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Opnav 34-P-0801

RADAR BULLETIN NO. 2 A

(RADTWO A)

THE TACTICAL USE OF RADAR IN AIRCRAFT

NAVY DEPARTMENT
OFFICE OF THE CHIEF OF NAVAL OPERATIONS

✦

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NAVY DEPARTMENT

OFFICE OF THE CHIEF OF NAVAL OPERATIONS

WASHINGTON

LETTER OF PROMULGATION

11 DECEMBER 1945.

1. This publication, THE TACTICAL USE OF RADAR IN AIRCRAFT, is issued for the use and guidance of the United States Fleet. Its principal purpose is to provide information concerning the physical and operational characteristics of airborne radar and allied electronics equipment.

2. This publication is effective upon receipt and supersedes Radar Bulletin No. 2 (RADTWO), all copies of which shall be destroyed by burning. No report of destruction is required.

3. This publication is [redacted] non-registered, and shall be handled, stowed, and transported as prescribed in Article 76, U. S. Navy Regulations, 1920. When no longer required for use, it shall be destroyed by burning, no report of destruction being necessary.

4. This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, 50 U. S. C., 31 and 32, as amended. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

5. While the classification of the publication is necessarily [redacted], commanding officers are urged to make certain that the book is available to all personnel whose duties require access to the information contained therein.

6. This publication is under the cognizance of and is distributed by the Chief of Naval Operations.

C. M. Cooke, Jr.

C. M. COOKE, Jr.,
DCNO (Operations).

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(RADTWO A)

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FOREWORD

The current effective USF tactical publications establish the necessary standard operating procedures for cooperative employment of naval units. These procedures are determined by evaluation of war experiences and the expected tasks to be assigned the various combinations of fleet units. By necessity these instructions are all inclusive and yet flexible so as to be applicable to the various tactical situations expected to be experienced by any specific fleet task organization.

Because the detailed employment of radar in all of its ramifications has become to an increasing extent inextricably a part of the successful execution of fleet tactics, USF 15 in its delineation of general tactical procedures involving radar, makes reference to the RAD series of official publications—supplementary publications which have been promulgated for the purpose of making available the current best practices in the arts of radar and electronics.

Of the several RAD publications now available or in the process of preparation, this publication, RADTWO A, concerns itself with the tactical use of radar and other allied electronic equipment in aircraft.

Used in aircraft, radar and other similar electronic devices provide the pilot fundamentally with information. It extends his sight under any condition of visibility, day or night; it furnishes quick and reliable navigation information; it provides a better and more accurate bomb sight; and, in some cases, it controls the accuracy with which his guns may be fired.

During the preparation of RADTWO A, because of the scope of the field encompassed, there was manifest a tendency to misconstrue the meaning of its title, "The Tactical Use of Radar in Aircraft." In order to prevent future possible misunderstandings of its purpose and content, it is emphasized here that RADTWO A describes just what its title implies, the tactical use of *radar* in aircraft . . . not the tactical use of *radar-equipped aircraft*. However, it has been attempted to indicate possible tactical uses of the electronic equipment without dictating the use of the aircraft. The fact that it is not always possible to divorce the use of the radar from the use of a radar-equipped plane is inescapable. Therefore, the information presented in RADTWO A is *not to be considered as doctrine.*

In contrast, however, to the seemingly confined viewpoint with regard to tactical use of radar in aircraft versus tactical use of radar-equipped aircraft, RADTWO A in its content has gone beyond a strict interpretation of its title by including information on equipments not essentially radar but certainly of an allied nature.

Such equipments as IFF, bombing attachments, beacons, loran, and electronic altimeters are not radar in the true sense of the word. Inclusion of descriptions of the use of such equipment in RADTWO A has been dictated by the fact that the theory and principles which underlie their function are closely allied to radar and, more important, in many cases radar-trained personnel are charged with their operation and use and should be cognizant of their complementary applications.

Since July of 1942, when the original RADTWO was published, certain early air-borne radar equipments have become obsolete because of technical advances. New air-borne radar systems and other electronic aids have been developed. In some equipments, simplification of control has gone ahead with increase in operating range; employment of higher radio frequencies has improved the resolution of targets as displayed on scopes; and developments of other electronic devices, some used in conjunction with radar, has made possible high- or low-altitude bombing, recognition and identification of friendly targets, beacon homing, and im-

proved navigation in almost any condition of weather or visibility.

RADTWO A is issued, therefore, to provide nontechnical information concerning the tactical application and use of air-borne radar and associated electronic equipments currently (August 1945) in use in the fleet.

It is felt that a true evaluation of the capabilities and limitations of air-borne electronic equipments cannot be made without first having some general idea of how these systems function. Each of the parts of RADTWO A, therefore, is prefaced with a theory section for the purpose of presenting a brief, nontechnical explanation of the fundamental principles underlying the operation of the electronic gear described in that part.

Those sections describing the operating characteristics and employment of specific air-borne electronic equipments are presented not as the final word but as a compilation of the most recent, operationally proven information available on the subject.

In presenting the material contained in RADTWO A, it will be noted that there has been a studious attempt to concentrate on radar and other electronic equipment as such, without reference to particular aircraft in which such equipment has been customarily installed. This intent has been deliberate because it was felt that, with conditions and values in the art of detection and ranging in a constant state of flux due to advances in design, engineering, and development; to associate a given piece of equipment with a given aircraft would have restricted RADTWO A's usefulness and limited its accuracy.

In the rapid development and production of electronics equipments designed for use in a multitude of types of naval aircraft, it was inevitable that during the period of time required for the preparation of this manual certain equipments would be superseded by improved equipments. For instance, the ASB series of air-borne radar equipments, although rapidly being replaced now by AN/APS–3 and AN/APS–4, was, from 1942 to early 1945, the sole air-borne equipment upon which full reliance was placed, particularly with regard to radar installations in carrier-based aircraft.

For the sake of completeness of the historical or chronological development of air-borne rader, and because of the fact that several of the basic features of design and operation of the ASB system are still contained in other electronic aids (AN/APX–8, AN/APG–4, the technical information concerning the L-type scope display and the ASB series equipments is retained in this manual. The same line of reasoning has dictated the retention of descriptions of such equipments as AN/APA–16, AN/ARN–1, and the YJ radar beacon.

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PART ONE

INTRODUCTION

I. NOMENCLATURE

An "AN Nomenclature System," used by both Army and Navy, has been developed to establish one standard plan of nomenclature for communication, noncommunication, and associated air-borne electronic equipments.

Under the "AN Nomenclature System" a typical model number might be as follows:

AN/APS–8B

The letters "AN" before the slant bar show that this is the new Army-Navy system of nomenclature. The first letter after the slant bar shows the type of installation; i. e., "A" for air-borne. The second letter after the slant bar shows the type of equipment; i. e., "P" for radar. The third letter after the slant bar shows the purpose for which the equipment is used; i. e., "S" indicates search, detection or interception equipment designated under the "AN" system of nomenclature. The number "8" indicates the model number; and "B" indicates the modification.

The following table lists the various designating letters used in this system, and their meaning.

LETTER SYMBOLS USED IN MAKING BASIC INDICATORS*

Installation	*Type equipment*	*Purpose*
A—air-borne (installed and operated in aircraft).	B—pigeon.	A—assemblies.
C—air transportable (designed to be air transportable as stated in specification or military characteristics).	C—carrier (wire).	C—communications (receiving and transmitting).
F—ground, fixed.	F—photographic.	D—direction finder.
G—ground, general ground use (includes two or more ground installations).	G—telegraph or teletype (wire).	G—gun directing.
M—ground, mobile (installed as operating unit in a vehicle which has no function other than transporting the equipment).	I—interphone and public address.	L—searchlight control.
P—ground pack or portable (horse or man).	M—meteorological.	M—maintenance and test assemblies (including tools).
S—shipboard.	N—sound.	N—navigational aids (including altimeters, beacons, compass, and instrument landing).
V—ground, vehicular (installed in vehicle designed for functions other than carrying radio equipment, etc., such as tanks).	P—radar.	Q—special.
T—ground, transportable.	R—radio.	R—receiving.
U—general utility, includes two or more general installation classes, air-borne, shipboard and ground.	S—special types (heat, magnetic, etc.).	S—search and/or detecting.
	T—telephone (wire).	T—transmitting.
	V—visual and light.	W—remote control.
	X—facsimile or television.	X—identification and recognition.

*An "X," "Y," or "Z," used after the main designation indicates a change in voltage, phase or frequency of the input power supply (AN/APX–8X). Suffix letters "A," "B," "C," etc., indicate a change in design (other than the voltage, phase, or frequency of the input) which will not affect the equipment's military characteristics or interchangeability of the equipment as a whole.

II. FREQUENCY BANDS AND FREQUENCY DESIGNATIONS

All conversational or written reference pertaining to the operating frequencies of air-borne electronic equipments should avoid mention of specific bands or frequencies unless it is absolutely necessary. Particularly, the practice of describing or classifying an equipment or system by naming its frequency or wavelength is dangerous. To avoid the necessity for this, the following code should be used wherever it will serve in lieu of naming specific frequencies or wavelengths. This list is classified RESTRICTED.

Megacycles	*Code*
10,900 to 33,000	K band
5,200 to 10,900	X band
1,650 to 5,200	S band
390 to 1,650	L band
225 to 390	P band

For a list of equipments and the frequency bands in which they operate see the table in the appendix, page 155.

III. CATEGORIES

Air-borne electronic systems and their associated equipments may be classified, for the purposes of this manual, into five broad categories:

A. Radar systems.
B. Radar beacons (racons).
C. Recognition systems.
D. Navigation systems.
E. Altimeters.

A. Radar systems. Air-borne radar systems are employed mainly for the purpose of detecting, at long range, through overcast, or under conditions of poor visibility, the presence of targets, and measuring their range and bearing.

In addition to its main function, a radar system may have one or more of the following specific uses:

1. Search.
2. Navigation.
3. Homing.
4. Bombing.
5. Interception.
6. Gun aiming.

Air-borne radars employed in combination with certain other electronic systems can also be used for:

7. Target identification.
8. Beacon homing.
9. Ordnance control:
   (*a*) Low- or high-altitude bombing.
   (*b*) Torpedo dropping.
   (*c*) Mine laying.
   (*d*) Gun sighting.

Part Two of this manual describes:

1. The theory and principles of operation of the radar system.
2. The physical and operating characteristics of air-borne radar equipments, and their tactical employment.

B. Radar beacons (racons). Radar beacon stations serve either meterwave or microwave interrogating equipments. Radar beacons comprise a means for receiving the pulses from radars or special interrogating equipment and using the received signal to trigger a relatively powerful beacon transmitter into operation.

The transmissions of a beacon station are gap- or range-coded to furnish its identity to the interrogating craft. On board the interrogating craft, the bearing of the beacon relative to the craft is indicated by the position of the antenna or of the signal display on an indicator. The range in nautical miles is read directly from the calibrated indicator screen.

Part Three of this manual describes:

1. The theory and principles of operation of radar beacons.
2. The physical and operating characteristics of radar beacons, and their tactical employment.

C. Recognition systems. Radar indicates the presence, range, and bearing of targets. Until such targets are positively identified as friendly, they are assumed to be "bogeys" (unidentified aircraft targets), or "skunks" (unidentified surface targets).

Air-borne electronic IFF (*I*-dentification *F*-riend or *F*-oe) equipment, when interrogated by shipboard, land-based, or other air-borne radars, operates to identify as friendly the aircraft in which it is carried. Some Mark III IFF air-borne equipment currently in use employs only a transpondor. Upon receipt of an interrogating signal, it responds with a coded reply to furnish identity.

Other Mark III IFF air-borne equipment, in addition to a transpondor, contains an interrogator-responsor unit. This unit is employed

to interrogate targets which appear on the radar scope, and to receive their replies which are then displayed on the scope.

PART FOUR of this manual describes:

1. The theory and principles of operation of IFF equipments.
2. The physical and operating characteristics of IFF equipments and their tactical employment.

D. NAVIGATION SYSTEMS. Through the use of a system called "loran" (*LO*-ng *RA*-nge *N*-avigation), lines of position and "fixes" can be obtained with an estimated accuracy of approximately 1 percent of the distance separating the craft from the special loran transmitting stations.

A loran system comprises three basic elements:

1. Loran transmitters (arranged in pairs).
2. Loran receiver-indicator.
3. Loran charts (or tables).

The loran transmitters, situated on islands or along coastal promontories, transmit short pulses at a low repetition rate. At a point out at sea, the time-difference in the reception of pulses from a pair of transmitters is displayed and measured on the screen of a cathode-ray tube (scope). On specially prepared loran charts, a line of position may be found which has the same time-difference designation as the time-difference reading obtained from the scope display. Obtaining a second time-difference reading from a second pair of transmitters provides a second line of position. A fix is indicated where one of the selected lines of position intersects the other.

Effective ranges of the loran system are:

	Nautical miles
Daytime	700
Nightime	1,400

The advantageous features of loran are:

1. Its use is independent of and not affected by adverse weather conditions.

2. No transmission from the aircraft or ship is required. It does not reveal an aircraft's position by the necessity of breaking radio silence.

3. Its effective range is greater and it provides a higher degree of accuracy than RDF systems.

4. It is a rapid yet highly accurate method of obtaining a fix. Three lines of position may be obtained in approximately 5 minutes.

5. It is limited to the use of friendly craft by virtue of the fact that only aircraft appropriately equipped can receive the pulsed signals and measure the time difference.

PART FIVE of this manual describes:

1. The theory and principles of operation of loran.
2. The physical and operating characteristics of airborne loran and its tactical employment.

E. ALTIMETERS. Electronic altimeters do not operate on atmospheric pressure principles. They indicate the altitude of the aircraft above the terrain directly below, regardless of the height above sea level of that terrain.

Electronic altimeters work on the following principles:

1. A frequency-modulated signal is generated, varying in frequency over a fixed frequency band.

2. A small portion of the generated signal is fed to the receiver, the major portion going to the antenna where it is directed toward the terrain.

3. The receiver, which accepts the returned transmitted signal, compares that frequency to the new frequency being generated at the time of reception and converts this frequency difference into current output.

4. The resultant current output actuates a meter, calibrated in feet, to indicate the absolute altitude. Altitude limit lights also give a general indication of altitude within prescribed limits.

The efficient employment of electronic altimeters depends upon the accuracy with which they are initially calibrated and the effectiveness with which they are maintained.

PART SIX of this manual describes:

1. The theory and principles of electronic altimeters.
2. The physical and operating characteristics of electronic altimeters and their tactical employment.

IV. SECURITY

Present security instructions concerning radar and radio equipments are quoted herewith:

(The letter which follows outlines current security doctrine. Omitted from RADTWOA are some thirty-five typewritten pages, constituting ENCLOSURE A, referred to in the following security classification letter, and containing specific security classification for each piece of naval electronic and communication gear now in use.)

NAVY DEPARTMENT
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON 25, D. C.

Op–413–B23/cvk
Serial 203P413
RESTRICTED 20 NOVEMBER 1945.

From: Chief of Naval Operations.
To: Chief of the Bureau of Ships.
Chief of the Bureau of Ordnance.
Chief of the Bureau of Aeronautics.
Subject: Electronics Equipment—Security Classification of.
References: (a) CNO restr ltr Op–25–A/ab, Serial 31825A dated 24 May 1945.
(b) CNO restr ltr Op–25–3/jeh, Serial 34725 dated 18 July 1945.
(c) Art. 76, U. S. Navy Regulations, 1920.
Enclosure: (A) Security Classifications of Eleectronics Equipments.

1. Reference (a) and (b) are hereby canceled. Enclosure (A) hereto, with respect to the equipments listed therein, supersedes enclosure (A) to reference (b).

2. The classifications assigned to classified equipments are based upon the need for maintaining military security. Equipment is classified when disclosure of any one or combination of the following may benefit a potential enemy to such an extent as to prejudice national interest:

(*a*) the use of certain newly developed or otherwise publicly undisclosed component;
(*b*) the use of certain newly developed or otherwise publicly undisclosed circuit;
(*c*) the use of certain newly developed or otherwise publicly undisclosed technique;
(*d*) the assembly of various units which individually are unclassified but which collectively satisfy the operational characteristics for a military application;
(*e*) the use of an unique manufacturing process; or
(*f*) the fact that the equipment is used by the Navy.

In promulgating these rules, Chief of Naval Operations appreciates that decisions involving technical details and their relations to military security must be determined by the Bureaus as prescribed in subparagraphs (7) (b) and (c) of reference (c). Accordingly, the addresses are requested to exercise care to avoid classifying individual components, circuits, or units of a complete equipment which is classified when those components, circuits or units do not satisfy at least one of the conditions stated above.

3. Attention is directed to items indicated by hatch marks (#). These items may contain some British influence; therefore, no technical disclosures thereon shall be made to the public until notified by subsequent correspondence that this restriction has been removed.

4. Reference (c) contains the instructions for safeguarding classified material. It should be noted that RESTRICTED documents, information or material may not be given to the public or to the press.

5. Recommended changes in or additions to enclosure (A) should be submitted to CNO promptly.

6. It is requested that the Bureau of Ships include in SHIPS 242A and the Bureau of Aeronautics include in CO–NAVAER 08–5Q–227, the security classifications of the equipments listed in enclosure (A), in order that the information may reach all activities which require that information.

(s) W. S. Farber,
W. S. FARBER,
Deputy Chief of Naval Operations (Logistics).

Authenticated:
W. A. HAMMOND,
Captain, USN.

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PART TWO

RADAR SYSTEMS

PRINCIPLES OF OPERATION OF THE RADAR SYSTEM

1. GENERAL

RADAR is a coined word. It means *RA*-dio *D*-etection *A*-nd *R*-anging.

Air-borne radars perform three main functions:

1. They detect the presence of targets.
2. They indicate relative bearing of the target from the aircraft.
3. They indicate in nautical miles the range of the target from the aircraft.

Certain basic radio phenomena contribute to the function of radar:

1. Radio waves generated at ultra-high frequencies have practically the same transmission properties as light. They travel from the transmitting antenna out to the horizon, and beyond, in straight lines on a line-of-sight principle. See figure 2–1.

2. The employment of ultra-high frequencies permits the use of relatively small, compact antennas which can be designed to concentrate the transmitted radio energy in a narrow path or beam; thus directional transmission and reception is obtained. See figure 2–2.

3. Objects which are in the path of beamed ultra-high-frequency transmissions reflect or reradiate a small portion of the transmitted energy back to the source. See figures 2–3 and 2–5.

Together, these three phenomena form the fundamental concept on which the operation of all radars is based.

To achieve its purpose of denoting the presence, bearing and range of objects (targets), a radar system employs certain basic units:

1. *The transmitter.*—Unlike conventional continuous wave radio transmitters, the radar transmitter generates ultra-high-frequency radio energy which is transmitted in short bursts or pulses. The pulsing cycle of a radar transmitter would look something like that shown in figure 2–4. Each pulse is on the order of one or two microseconds in duration, with relatively long rest or quiescent periods in between pulses during which the reflected echoes are received. For instance, a transmitter which pulsed 500 times a second with 2-microsecond pulses would have a rest period in between pulses of 1,998

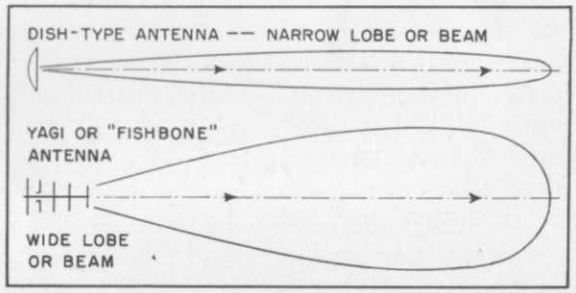


Figure 2–2.—Depending on the design of the antenna, the transmitter radio energy can be directed in a narrow lobe or beam.

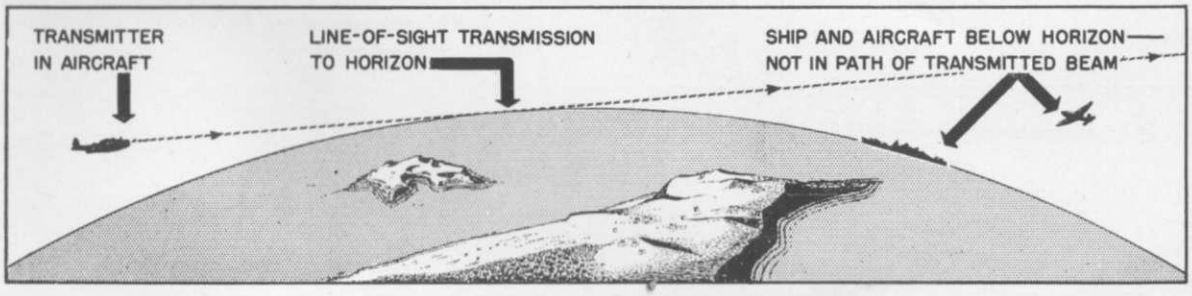

TRANSMITTER IN AIRCRAFT
LINE-OF-SIGHT TRANSMISSION TO HORIZON
SHIP AND AIRCRAFT BELOW HORIZON— NOT IN PATH OF TRANSMITTED BEAM

Figure 2–1.—Radio waves generated at ultra-high frequencies have practically the same transmission properties as light waves. They travel from the source out to the horizon and beyond on a line-of-sight principle.

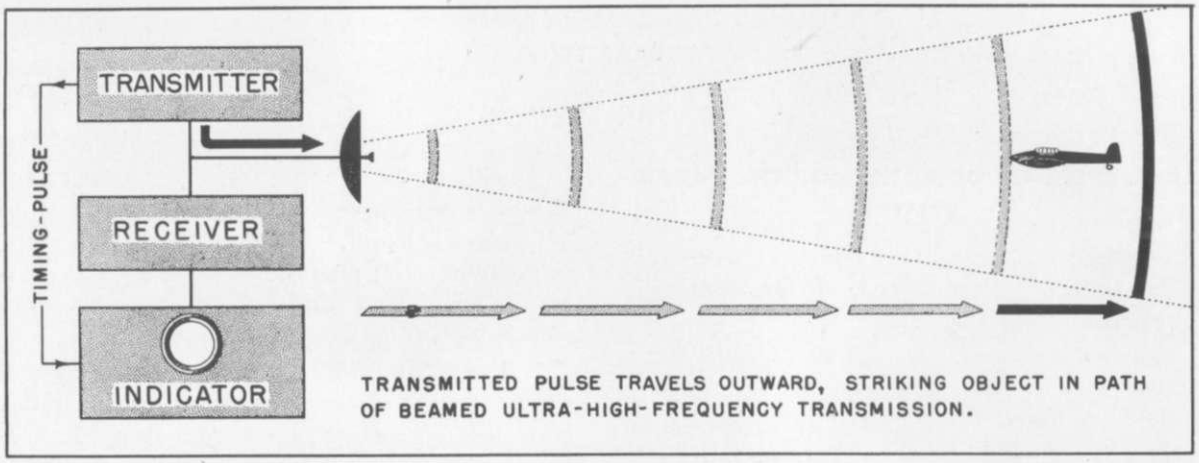


Figure 2–3.—In this diagram a single pulse is shown, the shaded arrows in the beam denoting the progressive positions of the outward-going pulse as it travels from the directive antenna.

microseconds. Because radio waves travel at a constant velocity of 162,000 nautical miles per second, the time (during the rest period) required for a pulse to travel out to the target and return as a reflected echo would depend upon the distance of the target from the transmitter.

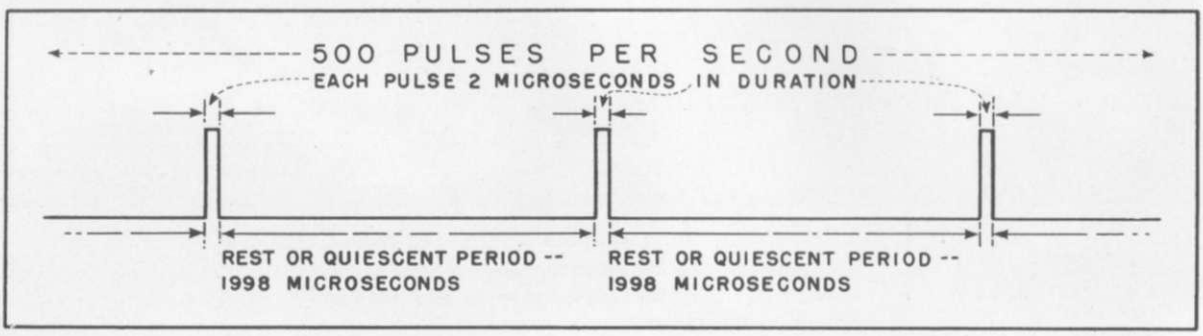
2. *Directional antennas.*—The pulses generated by the transmitter are fed to a directional antenna which transmits them into space in a narrow beam. An object in the path of the beam will reflect back a small portion of the pulse energy. Early types of radar employed fixed directional antennas which transmitted the beam of radio energy out to either side of the aircraft, or straight ahead. Later equipments employed a movable type of antenna which could be rotated manually from abeam to ahead. The newer types employ an electrically driven antenna which either oscillates through an arc of 150° ahead of the aircraft or rotates through 360° of azimuth.

3. *Receiver-indicator system.*—Back on the aircraft, the reflected pulse energy is received by the antenna, amplified in the receiver and passed along to an indicator unit containing a special timing device—a cathode-ray tube—which translates into terms of range the elapsed time that it took for the transmitted pulse to go out to an object and return to the radar as a reflected echo. One the cathode-ray tube screen (scope), the range of the target is indicated by the position of the target echo on a calibrated time trace. The bearing from which an echo returns is determined by utilizing the directional characteristic of the antenna system, and synchronizing it with the scope display.

II. TYPES OF SCOPE PRESENTATION

The diagrams, figures 2–3 and 2–5, show the relationship of the indicator to the other basic

Figure 2–4.—Radar transmitters send out pulses of radio-frequency energy many times per second. These pulses vary in duration from—about ½ to 2 microseconds (millionths of a second). Depending upon the range for which the equipment is designed to operate, the quiescent or inoperative period between pulses is long enough.


500 PULSES PER SECOND
EACH PULSE 2 MICROSECONDS IN DURATION
REST OR QUIESCENT PERIOD -- 1998 MICROSECONDS
REST OR QUIESCENT PERIOD -- 1998 MICROSECONDS

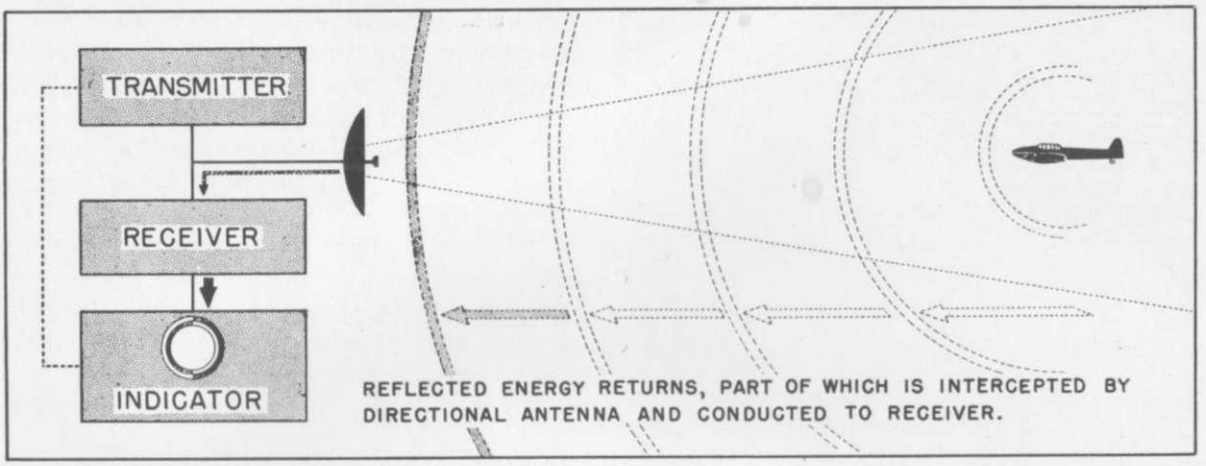

TRANSMITTER
RECEIVER
INDICATOR
REFLECTED ENERGY RETURNS, PART OF WHICH IS INTERCEPTED BY DIRECTIONAL ANTENNA AND CONDUCTED TO RECEIVER.

Figure 2–5.—When the outward-going pulse strikes an object in its path, a small amount of radio energy is reflected back toward the source where it will be displayed on the indicator as a visual signal.

radar system units. Each time that the transmitter furnishes a pulse to the antenna, a minute quantity of pulse energy is fed to the indicator where it is used as a timing pulse to cause a spot of light, visible on the cathode-ray tube screen, to form a time trace.

There are two methods in use by which a target echo is made to register its presence on the time trace. One method is called the "blip type" and the other is called the "spot type" indication.

A. Blip type. 1. *L-scan.*—Early type air-borne radar equipments, such as the ASB, employ what is termed an L-type scope presentation where the spot of light, in synchronization with the pulsing of the transmitter, appears first at the bottom center of the screen and moves upward vertically as the pulse travels outward through space. The recurrence and movement of the spot is so rapid that, to the eye, a vertical bar of light, called the time trace, is formed. It is calibrated in terms of range. See figure 2–6.

Received radar echoes cause the rapidly moving spot of light to detour momentarily in its upward path to form jagged pointers of light out from the side of the trace. This is called the blip type of indication, the blip appearing at a distance upward from the bottom of the trace proportional to the time that it took for the transmitted pulse to go out from the antenna, strike a target, and return to the radar in the form of a week, reflected target echo. The bearing of the indicated target is determined by noting the position of the antenna when maximum lateral length of blip is obtained.

2. *A-scan.*—Some equipments (ASG, AN/APS–2, AN/APS–15, etc.) employ a monitoring A-scope which is similar in operation to the L-type scope excepting that a horizontal trace is employed and signal voltages produce blips which appear up from and along the trace.

B. Spot type. Later air-borne radar equipments utilize spot-type scope displays which in-

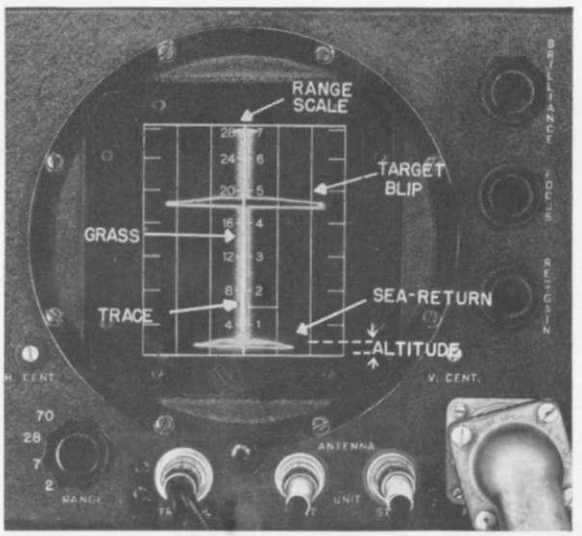


Figure 2–6.—The L-type scope is the ASB indicator. A rapidly recurring spot of light forms a vertical trace. Signal voltages applied to deflecting plates within the cathode-ray tube cause the spot to momentarily detour literally, producing the target blips.

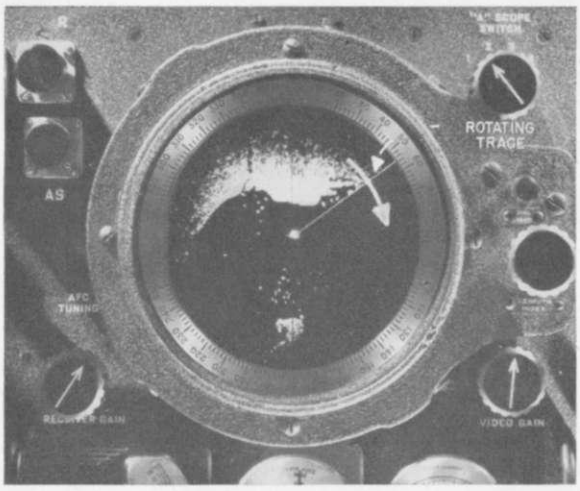


Figure 2–7.—This is the PPI-type scan. Rotating in step with the antenna a radial trace has portions of its length intensified by the reception of reflected pulses causing a pattern to be "wiped" on the face of the PPI tube. For purposes of illustration the brilliance of the trace has been increased in the scope presentation above. In actual practice the brilliance of the trace is brought up to a point to where it is barely visible.

clude the PPI (circular map), the B-scan (square map), the H-scan and O-scan (double dot), and the G-scan (growing wing) types of scope presentation. Some radars use combinations of these scope presentations. (AN/APS–4 uses B-scan and H-scan; AN/APS–6 uses B-scan and G-scan.)

1. *PPI-scan.*—In radar equipments employing the PPI type of presentation (fig. 2–7), the dish-type antenna revolves through 360° of azimuth. On the scope screen of the indicator, the rapidly recurring spots of light form a radial time trace which rotates in synchronism with the rotation of the antenna. Target echoes are displayed on the screen as a momentary intensification in the brilliance of a portion of the revolving trace. They appear at points outward from the center of the screen, along the trace, to indicate azimuth and range of the target. Because of the persistence of the screen's fluorescent coating, the target images remain in view, diminishing in brilliance after the trace has swept past. (This type of spot presentation is found in such airborne radars as the AN/APS–2F and AN/APS–15.)

2. *B-scan.*—In the B-scan or square map type (fig. 2–8), a dish antenna mechanically sweeps from side to side through a 150° arc to scan a fan-shaped area ahead of the aircraft. On the scope screen of the indicator, the rapidly recurring spots of light form a vertical time trace which moves from side to side across a rectangular screen in synchronism with the antenna movement. The echo from a ship or other relatively small target will cause a momentary intensification in the brilliance of a small portion of the trace to produce a spot of light. The distance at some point upward from the bottom of the trace at which this spot appears is proportional to the target's range. Echoes from land masses or large targets will cause a correspondingly greater portion of the trace to increase in brilliance during the period of scan.

As the trace moves from side to side across the screen, its intensified portion "wipes" the target images on the scope in the form of a brilliant light pattern which, because of the relatively high order of persistence of the fluorescent screen coating, remains visible after the trace has swept past. (This type of spot presentation is found in such air-borne radars as the AN/APS–3 and AN/APS–4.)

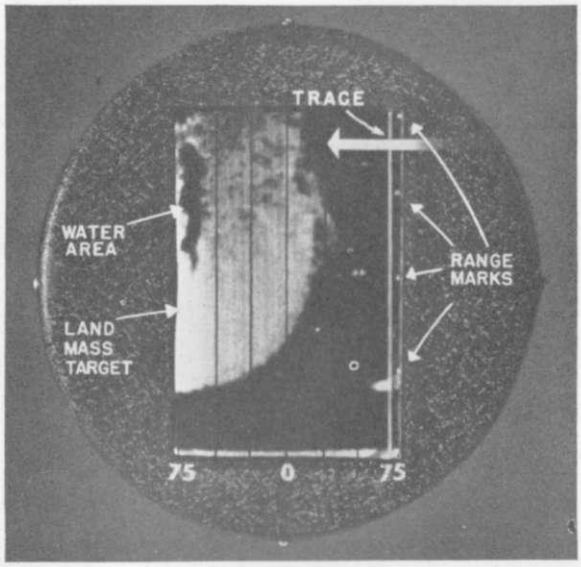


Figure 2–8.—In the B-type scan a rectangular area is covered by the vertical trace which moves from side to side in step with the scanning movement of the antenna. Target areas produce reflected echoes which intensify a portion of the trace, forming a light pattern on the scope face. Because of the relatively high persistence of the fluorescent coating on the tube face, the pattern is retained momentarily after the trace moves by.

B-scan distortion.—In the B-scan, or square-map type of scope presentation, the fan-shaped area being scanned is represented on the scope screen as an illuminated rectangle. A fan-shaped scope screen could be provided but it would have the disadvantage of crowding targets at the apex of the triangle. Moreover, the crowding would become decidedly pronounced as the range to the target was closed, making definition of separate targets difficult if not impossible.

By virtually spreading out the apex area and producing a rectangular display, the crowding effect is overcome; but it introduces two separate distortion effects for which mental correction must be made in interpreting scope patterns on the rectangular screen.

The first distortion effect is particularly noticeable with large land-mass patterns or ships in column. See figure 2–9. Suppose that the range from the aircraft to the target dead ahead, "D," is 6 miles; the range to the other targets in column of ships would vary. To the "A" and "G," the range would be 10 miles; to "B" and "F," 8 miles; to "C" and "B," 6½ miles.

On the scope, instead of being located across the screen in a straight line, "A" and "G" would appear at the 10-mile range, "B" and "F" at

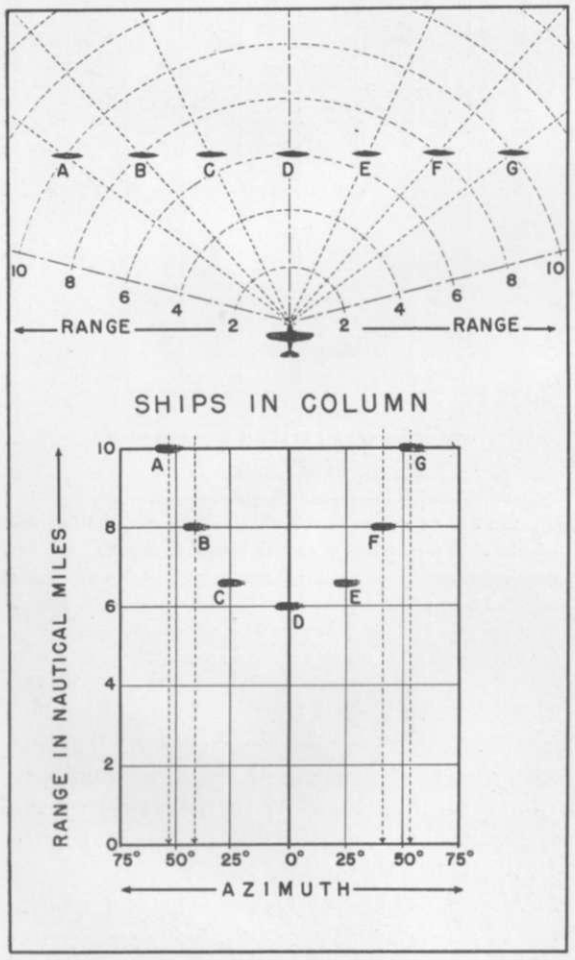


Figure 2–9.—At the top is shown a column of ships as they would appear under conditions of good visibility to an observer in an aircraft. Note the range and bearing to each of the ships. The lower half of the figure shows how these same ship targets would appear on scopes employing the B-scan display. Mental correction must be made for the apparent distortion introduced by the rectangular scan.

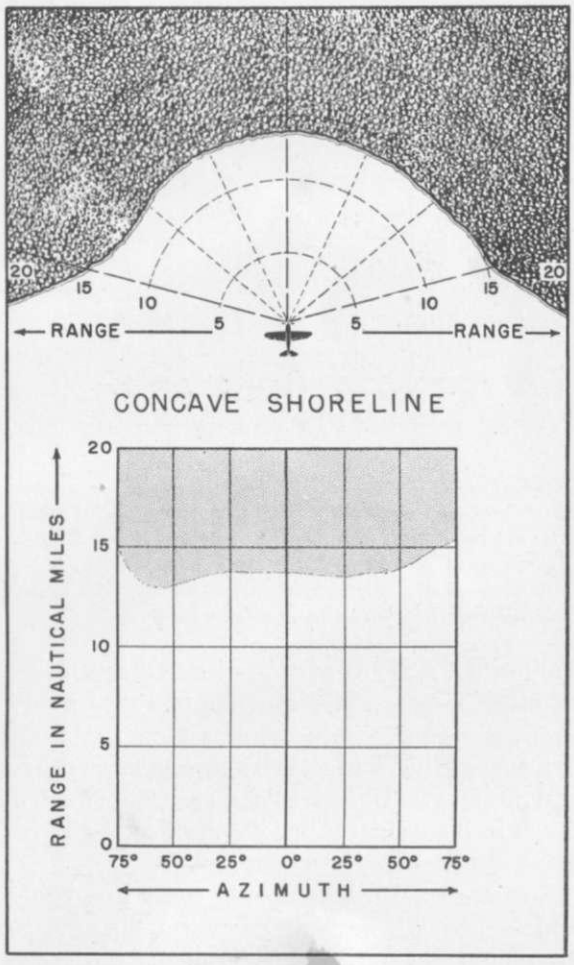


Figure 2–10.—Because the fan-shaped area being scanned ahead of the aircraft is represented as a rectangular pattern, the radar images are distorted. Here a concave shore line whose various points are approximately equidistant from the aircraft is represented on the scope as a land-mass pattern whose shore line is practically a straight line.

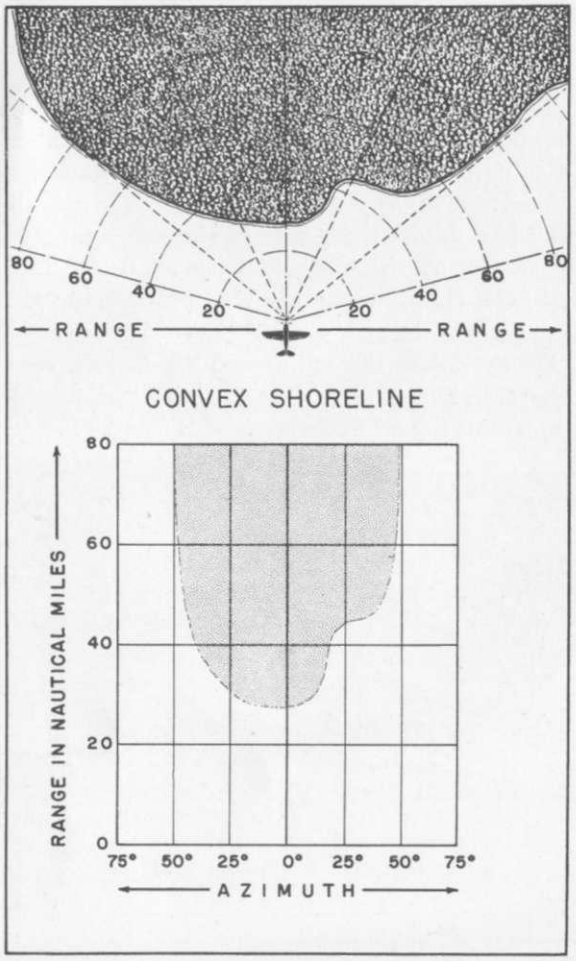


Figure 2–11.—When a shore line being scanned is irregularly convex as shown here, the scope pattern appears with an exaggerated curvature. Upon inspection, however, points of reference on the land area appear correctly with respect to range and azimuth on the scope pattern.

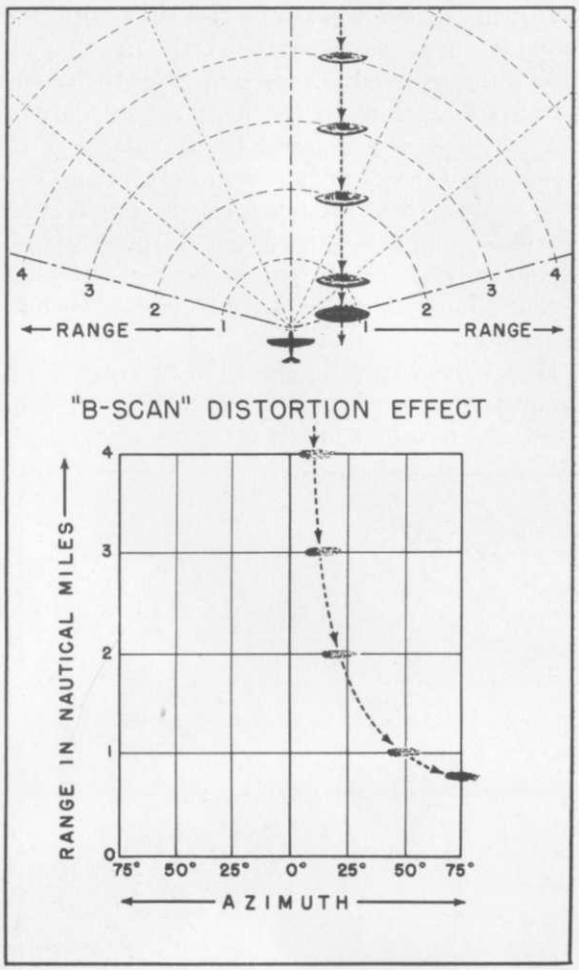


Figure 2–12.—As shown in the sketch at the top, the bearing of the ship target alters as the range is closed. On the scope, because the apex of the fan-shaped area being scanned is in effect stretched out to form a rectangle, targets to either side of dead ahead as they are approached appear to rapidly drift off to the side of the scope.

8 miles, "C" and "E" at 6½ miles, "D" at 6 miles. In other words, a straight line of ships would produce target echoes displayed on the scope in a curved line, but actually correct as to range and bearing. Unless this distortion effect is taken into consideration, it complicates the interpretation of pattern contours.

In figure 2–10, because the coast line being approached is concave, the radial distance to all points along the coast is about the same. Therefore, on the scope the coast line appears approximately as a straight line. A convex coast line, on the other hand, looks like that shown in figure 2–11.

The second distortion effect is particularly noticeable with respect to the bearing of nearby targets as the range is being closed. Targets slightly off to either side of dead ahead appear to move rapidly outward to the edges of the rectangular screen during the approach. Figure 2–12 illustrates this point.

3. *H-scan.*—The AN/APS–4 is one of the types of air-borne radar equipments employing the H-scan (in addition to the B-scan). When this equipment is set for Intercept, a 6° beam from the antenna scanner is made to sweep from side to side over a rectangular area ahead of the longitudinal axis of the aircraft, 150° in azimuth and 24° in vertical plane. This back-

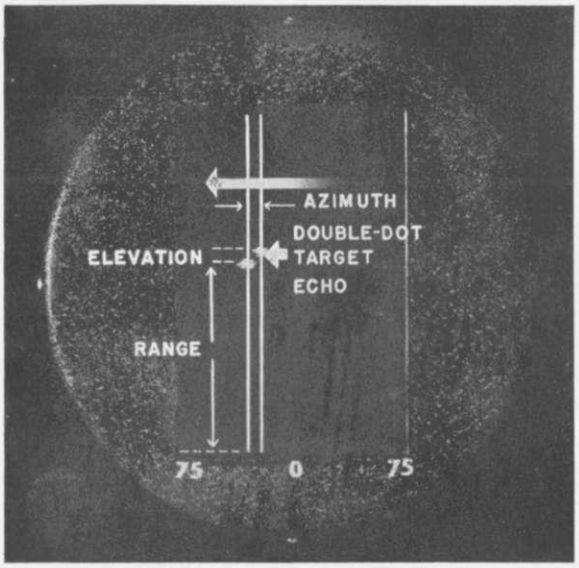


Figure 2–13.—When set for Intercept the AN/APS–4 equipment produces a scope pattern consisting of two dots (an echo and shadow pip), formed by the lateral sweep of a double trace moving from side to side across the screen.

and-forth motion takes place about 60 times a minute.

On the rectangular screen of the scope, a single trace moves from side to side in synchronism with the azimuth sweep of the scanner. With respect to the scope presentation, the position of the intercepting aircraft is considered to be at the lower center of the screen. Another aircraft within the field of the beam will reflect echoes which are displayed on the scope screen as two spots of light, termed "pips." The pip at the left is called the echo pip, its location on the scope screen denoting the target's range and azimuth. The pip to the right of the echo pip is called a shadow pip. Its angular position with respect to the echo pip denotes the relative elevation of the target. The two pips move about on the screen together. When the interceptor aircraft is maneuvered so that the echo pip lies on the central scribed azimuth line, the target is dead ahead. When the interceptor aircraft is maneuvered so that the shadow pip is aligned horizontally with the echo pip, the target is in line with the longitudinal axis of the interceptor aircraft. See figure 2–13.

O. *O-scan.*—The O-type scan, whose scope presentation is somewhat similar to the H-scan, is employed in air-borne radar equipments especially designed for interception (fighter aircraft). In the O-type presentation, the scan or sweep of the antenna is produced by the combination of two movements of the spinner. One movement rapidly rotates the antenna dish 1,200 r. p. m.; the other movement sweeps the antenna assembly through 60° from dead ahead to the outer limits of the 60° angle and returns to center. This cycle occurs once every 2 seconds. As a result of these two movements, an outward-inward spiral motion is imparted to the antenna to sweep the 9° antenna beam spirally through a 120° conelike area ahead of the longitudinal axis of the aircraft.

On the O-type scope screen this antenna action is translated into the movement of two vertical traces which start at the vertical center of the screen and move outward, then inward, in synchronism with the outward and inward spiralling motion of the antenna. On the screen the opening and closing movement of the two traces is referred to as the "barn door effect."

Target echoes are of the "double-dot" presentation, similar to that obtained in the H-type scan. The azimuth position of the target is in-

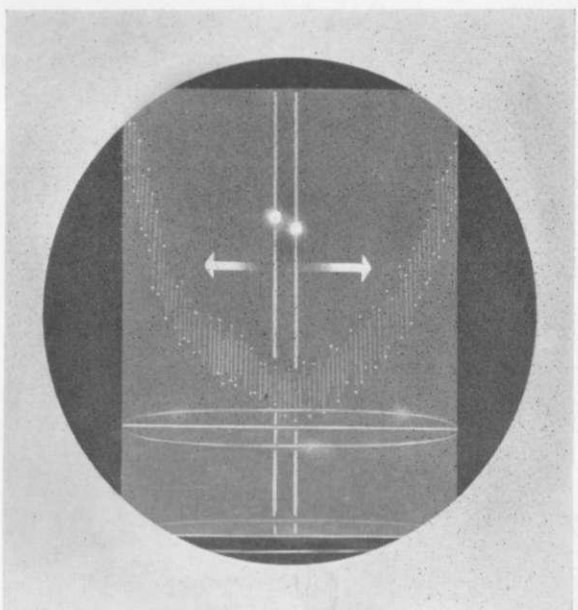


Figure 2–14.—In the O-type scan a spiralling antenna motion is translated on the scope screen into the movement of two vertical traces which start at the vertical center of the screen and move outward and inward to produce the pattern shown here.

dicated by the position of an imaginary line between the two dots. In addition to the double-dot presentation, a sea-return and altitude echo is displayed.

The sea-return pattern, curtainlike in effect, represents the echo reflection from the area where the spiralling outer edge of the cone of energy strikes the surface of the sea ahead of the aircraft.

The altitude mark is a straight brilliant line of light appearing upward from the bottom of the rectangular scope screen at a distance proportional to the aircraft's altitude. The O-type scope display is illustrated in figure 2–14.

5. *G-scan.*—The AN/APS–6 series of air-borne radars employ three separate types of scope display: (1) the B-type scan for search, (2) the O-type scan for intercept, and (3) the G-type scan for gun aiming. After a target is brought to close range by the use of the intercept scope presentation, (O-scan) the AN/APS–6 series of radars may be set to produce still another type of scope presentation—the G–scan for gun sighting. When set for Sight, the antenna spinner movement is altered to eccentrically rotate the 9° beam, producing a 10° cone bore sighted with respect to the forward-firing guns.

On the scope, the target is identified as a bright spot whose radial position with respect to the center of the screen denotes the relative azimuth and elevation of the target aircraft. When the interceptor aircraft is maneuvered to cause the spot of light to rest in the center of the scope, the target aircraft is bore sighted dead ahead. As the range is closed, the spot grows wings whose tips, when they touch vertical lines scribed on the scale face, indicate that the target aircraft is within firing range. See figure 2–15.

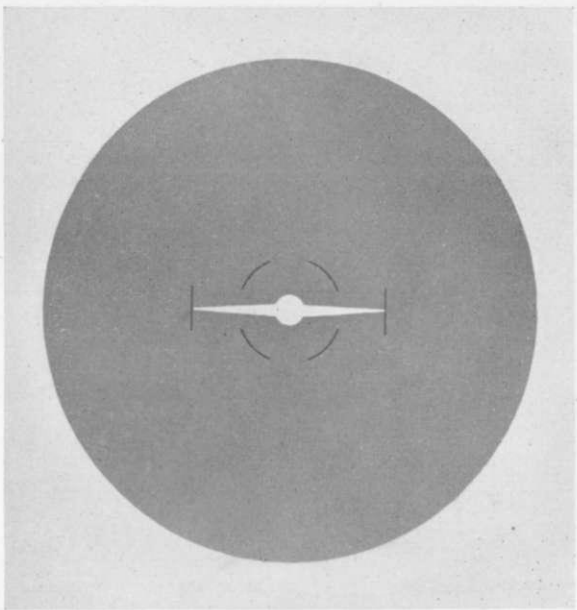


Figure 2–15.—The G-type or gun aim scan produces a spot of light when a target is within range of the conical antenna beam. The radial position of the spot of light denotes bearing in elevation and azimuth. Maneuvering the aircraft to put the spot in the center of the scope places the target dead ahead. As the range is closed the spot grows wings. When the wings touch the scribed markings the target is at firing range.

III. RANGE MEASUREMENT

In all types of air-borne scope presentation (with the exception of the G–scan), it should

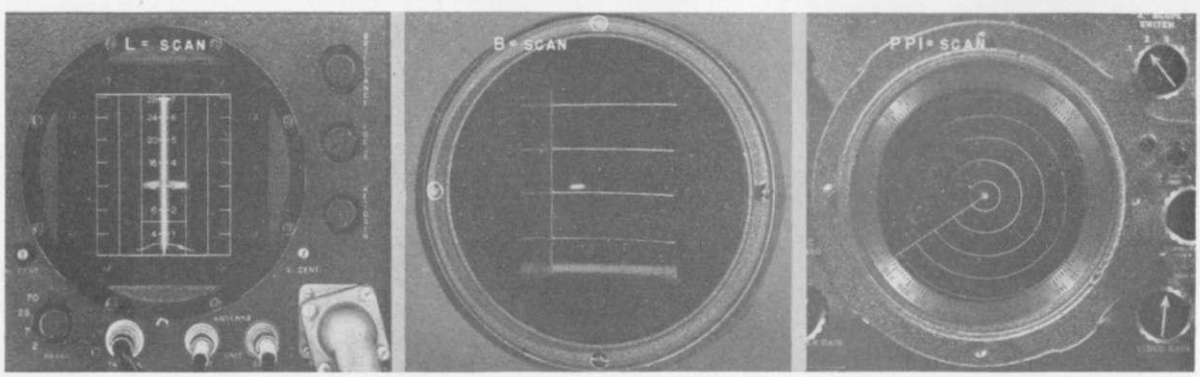


Figure 2–16.—A graduated plastic scale placed over the face of the L-type scope (left, above) provides a ready reference for estimating target range. In the B-scope (center) bright spots on the vertical trace produce horizontal range marks for judging range. On the PPI-scope (right, above) electronically generated bright spots on the trace leave range circles on the scope face.

be borne in mind that the time trace, whether it be stationary as in the L-type, revolving as in the PPI-scan, or laterally oscillating as in the B- and H-scan, represents a time-measuring device which is calibrated to indicate range in nautical miles.

The L-scan uses a calibrated scale etched on a transparent plastic material which is placed over the face of the scope to assist in determining the range of a blip. In the other presentations (PPI, B- and H-scans), electronically generated bright spots of light appear along the length of the trace at accurately spaced intervals. In the B-scan, these bright spots on the trace activate the fluorescent coating of the scope so that as the trace moves back and forth, it produces lines of light called range marks. In the PPI-scan, circular range marks are similarly formed by the spaced bright spots on the trace as it revolves in step with the antenna. See figure 2–16. (In the H-scan, range mark spots appear only at the extreme right vertical edge of the rectangular scope screen.)

IV. FACTORS WHICH LIMIT ALL RADAR PERFORMANCE

A. Variable factors. Maximum ranges claimed for particular radar equipments are not always obtained. Different conditions of flight, weather involving electrical disturbances, and other phenomena, will cause variations from day to day and from hour to hour in maximum ranges of detection. The following "variables" affect the performance of all radar equipments:

1. *Altitude.*—Under normal conditions, the beam from the radar antenna travels along a line of sight to the horizon. The higher the altitude, the greater is the distance to the horizon; therefore, range is limited by the altitude at which the plane flies. The chart, figures 2–17, shows, in nautical miles, the approximate radar line-of-sight range to the horizon for the altitudes listed. The distances given apply to targets at sea levels; an increase in target height extends the line-of-sight range to the target.

2. *Sea and ground return.*—Although most of the ultra-high-frequency radio energy is concentrated by directive antennas into a narrow beam or lobe, some of this energy is projected downward from the aircraft where it strikes the land or sea below. Radar reflections from

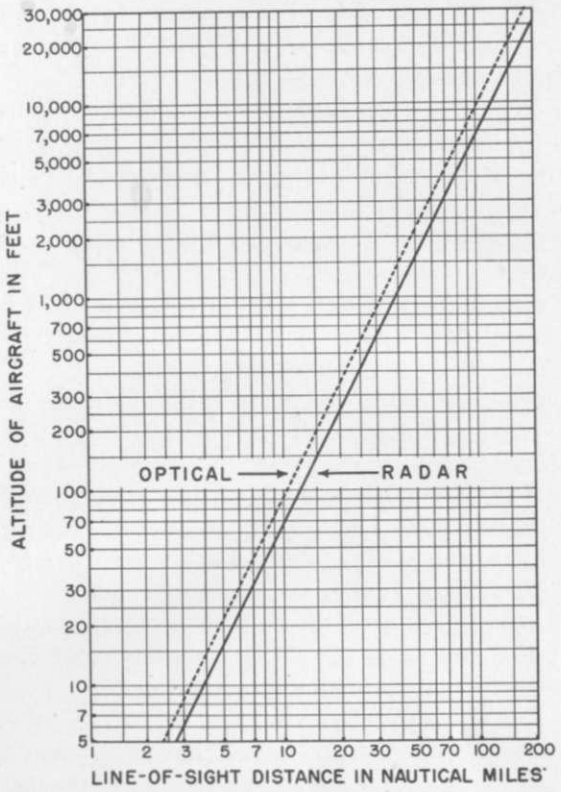


Figure 2–17.—Because radio waves are bent down slightly by the ionosphere their path is larger than the line-of-sight distance to the horizon. This graph illustrates the approximate line of sight and radar distances obtained at altitudes up to 30,000 feet.

the land or sea directly below the aircraft return and show upon the scope screen as a diffused, irregular pattern close to the start of the trace. The area on the scope covered by such land or sea return depends largely on the altitude of the aircraft. At low altitudes, a small area is covered. Consequently, a small area about the start of the trace is covered by the returning echoes. At high altitudes, a correspondingly larger area of the scope is covered by the return because the stray radiation covers a larger area below the aircraft.

Land areas below the aircraft usually cause stronger, larger returns because the ground offers more and varied reflecting surfaces. Areas of sea below the aircraft return weaker, fewer returns because of the relatively flat surface intercepted by the stray radiations. In a rough sea, however, the advancing front of waves offers good reflecting surfaces and, in

addition to increasing the area of sea return on the scope, indicates generally the direction of the wind causing the high seas.

3. *Target size, shape, and substance.*—In general, large targets return echoes at greater ranges than small targets. A target that is broadside to the radar beam will return echoes from greater distances than a long but narrow target which is bow-on to the radar beam. The material of which the target is made has a decided effect upon the strength of the echo which it returns. Metal targets are detected at greater ranges than nonmetallic targets. A steel ship, for example, is detected at greater ranges than a wooden ship.

4. *Fading.*—Distant targets often fade in and out much like the fading of radio signals from a distant broadcasting station. Aircraft targets, in particular, usually fade rapidly on the radar scope, and reappear just as rapidly. One cause of this fading is the changing attitude of the reflecting surfaces of the target.

5. *Nonstandard propagation of radio waves, trapping, ducts—a. General Features.*—As a general rule, and in accordance with the accepted theory of wave propagation, it has been assumed that waves generated at frequencies above 30 megacycles travel from a transmitter outward along a long of sight and, with respect to radar, that targets in the line of sight will reflect a portion of these waves back to the source also along a line of sight. This has been and still remains the basic premise on which the explanation of the operation of radar is based. Reports on the variability of radar coverage show, however, that certain weather and atmospheric conditions prevailing along the transmission path may greatly modify the day-to-day and hour-to-hour normal radar range characteristics.

In order to establish a reference for the purpose of investigating the effect of atmosphere on radio wave propagation, a so-called standard atmosphere has been postulated. The standard atmosphere is likely to be found in nature when the air is well mixed so that no unusual temperature or humidity gradients can exist. A standard atmosphere may be defined as that condition of the atmosphere in which the temperature and moisture content of the air decreases uniformly with height.

In the standard atmosphere, the air temperature decreases with increasing altitude at the rate of 6.5° C. per kilometer from 15° C. at sea level. Although this condition is postulated as "standard," it is not necessarily normal at any particular location. The atmosphere is likely to be of standard composition when strong, gusty winds are blowing, because the turbulence created prevents both stratification of the air and establishment of nonstandard temperature and humidity gradients. Standard propagation is likely also when the water is colder than the air, or over land when cooling of the earth by radiation is limited by overcast skies. If rain is falling, the lower atmosphere in general will be saturated with water vapor, so that the existence of abnormal humidity gradients is prevented and propagation should be standard.

In the standard atmosphere both the air temperature and the moisture content decrease uniformly with height above the surface of the

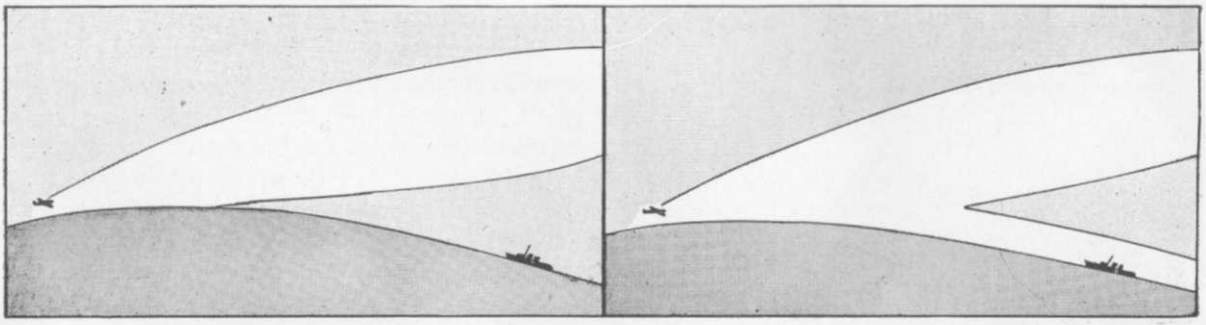


Figure 2–18.—A. Radar lobe pattern in standard atmosphere. Steady variation of temperature and humidity aloft.

Figure 2–18.—B. Radar lobe pattern in nonstandard atmosphere. A duct has been formed on the surface and ship is detected.

earth, so that the index of refraction of the atmosphere also decreases uniformly. However, the atmosphere is subject to many changes. The temperature may, for example, first increase with height and then begin to decrease. Such a situation is called a "temperature inversion." More important, the moisture content may decrease markedly with height just above the sea. This latter effect, which is called a "moisture lapse," either alone or in combination with a temperature inversion, may produce a great change in the index of refraction of the lowest few hundred feet of the atmosphere. The altered characteristics of the atmosphere may result in an excessive bending of the radar waves that are passing through the lower atmosphere. In certain regions, notably in warm climates, excessive bending is observed as high as 5,000 feet. The amount of bending in regions above this height is almost always that of normal atmosphere.

The atmosphere must be relatively calm in order to permit the existence of the conditions that produce this excessive bending. After a period of calm or of light breezes, the lower air may be stratified so that nonstandard propagation is likely throughout a wide area. There will be formed within this area a sort of duct or wave guide in which the radar waves can be trapped. The most remarkable effect of such trapping is the extreme ranges that have been obtained as a result of it.

Numerous instances have been reported where the normal radar horizon range has been increased four or five times, while a few hours later, the same radar has failed entirely to detect targets clearly visible to the eye.

The duct in the atmosphere may be formed along the surface of the sea or elevated above the earth. In either case, the coverage of the radar will be changed by the great extension of detection range for targets within the duct. In figure 2–18, one possible type of deformation of a radar coverage pattern is illustrated. The duct acts very much like a wave guide that is used as the transmission line in the radar set. The humidity gradient is such that the rays from the radar antenna are bent an excessive amount, and they are trapped in a zone near the surface of the water. Since the effect of the duct is to guide the radiated energy around the curvature of the earth and back again to the antenna, the radar is able to detect the ship at a range much greater than normal.

If the moisture content of the air increases with height, the radar waves may be bent up instead of down. Nonstandard propagation of this sort reduces the radar coverage instead of increasing it.

b. Effect on radar performance.—The position of the radar antenna relative to the duct in the atmosphere is one of the most important factors in controlling the effect of trapping. The radar pulse can be trapped and carried out to very distant targets and back to the radar if the antenna lies within the duct. If the antenna lies below the duct, trapping may take place, but only if the radiated rays from the antenna enter at a very small angle. For this reason, elevated ducts that are very high will not have any direct effect on radar performance. On the other hand, if the antenna is a small distance above the top of the duct, blind zones may be present in the low-level portion of the coverage pattern that do not exist during standard propagation conditions. However, if the antenna is high above the top of the duct, as an airplane flying over a ground-based duct, no effect on the air-borne radar coverage will be apparent.

Since the ducts that are most important to the operation of shipboard radar are ground based, radars that have relatively low antenna heights are the most likely sets to experience trapping. Experiments and observations of shore radar installations in both the United States and England have indicated that low sites are rather generally affected by trapping while high sites experience the phenomenon relatively infrequently.

For some time after the discovery of trapping it was thought that the long ranges observed resulted from the diversion of a large amount of the radiated energy into the duct. Consequently, it was feared that the existence of trapping would cause a great decrease in coverage in the area above the duct. However, the conditions that exist in the most common type of trapping do not support this presumption. In spite of the great increase in ranges

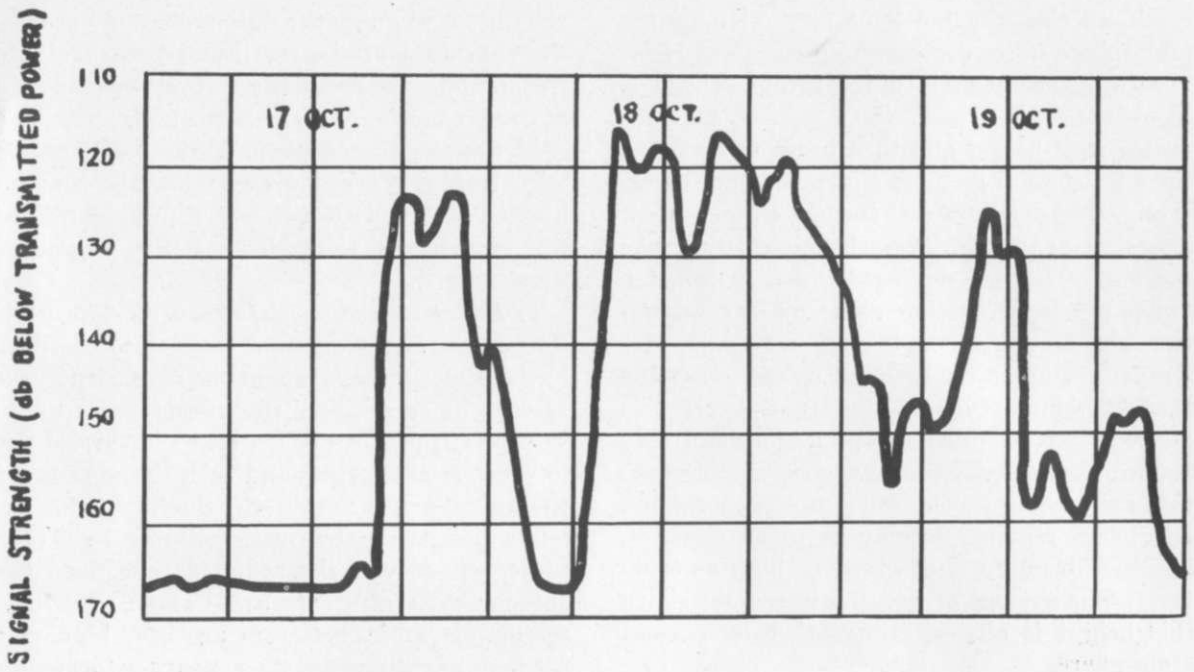


Figure 2–19.—Variation of echo amplitude with constant radar performance.

in the duct, the amount of energy trapped is small compared to the total energy radiated in the pulse. The increased range apparently is caused by the increased transmission efficiency that exists within the duct.

In many cases, coverage will be reduced for targets that are just above the duct. This reduction is caused by the wave-guide action of the trapping layer. The radiated pulse is contained within the duct because the refractive power of the atmosphere within this region is such that the radiated rays are bent downward. Directly above the duct there may then be little or no energy, and targets flying there may not be detected. However, energy may reach targets that are well above the duct by traveling along paths that enter the trapping region at angles too great to be trapped.

The wavelength that can be trapped in the duct formed by nonstandard propagation conditions varies with the height of the duct. If the duct is approximately 400 feet high, all radar frequencies can be trapped within it. However, if the duct is only 100 feet high, only microwave energy will be affected. A duct almost always exists within perhaps the first 20 feet above the water, but this is not yet of any practical use since only K-band energy could be trapped within such a narrow region. There is fairly conclusive evidence of the rather general existence of a surface duct 50 to 65 feet high throughout the trade wind area of the Pacific Ocean. This duct is capable of trapping S-band and shorter wavelengths provided the antenna lies within the duct. Because of the characteristics of the ducts that are usually formed, radar frequencies below approximately 250 megacycles are the least likely to be trapped.

The amount of refraction, that is, the amount of angular deflection of the rays, is very small and very rarely will exceed 1°. Such bending does not affect radar operation except in regions where the angle between the radiated ray and the horizontal is very small.

Only low-angle search is affected by meteorological conditions; performance of the radar is rarely affected by weather for targets above approximately 1° position angle.

A very serious operational consequence of trapping is the misleading of radar operators as to the over-all performance of the equipment. Long-range echoes caused by trapping have frequently been assumed to indicate good condition of the equipment when precisely the op-

posite may be the case. For example, figures 2–19 shows a part of a record of echo amplitude taken during an investigation of radar propagation. The performance of the radar was maintained at a constant level by the use of an echo box. The target was 30 miles away from the radar, with the path of the pulses passing over sea. Aside from the rise and fall of the tide, the variations in echo strength are due to changing characteristics of the targets or of the propagation pathway. The tremendous variation shown in figure 2–19 would certainly preclude the use of this target as a standard to check the performance level of a radar. At one point in the curve, the echo changed two-hundred-thousand-fold (53db) within 2½ hours. However, the phenomenon of trapping does not invalidate the measurement of echo height on nearby targets as a criterion of over-all set performance, since the echoes from objects well within the optical horizon are not affected appreciably by propagation variations.

Under conditions where the security of radar transmissions is involved, the possibility of trapping should be constantly kept in mind. When a duct is present, the enemy can intercept both radar pulses and VHF communications at far greater ranges than normal. When trapping is known to be present, and a choice of frequencies is available, it may be better to choose the lowest band since the high frequencies are the more likely to be trapped. Thus, decisions as to when to employ radar silence must be modified by consideration of propagation conditions.

Trapping may be the cause of apparently inexplicable failure in communications. Elevated ducts do not have much effect on ship-to-ship or ground-to-ship communications unless the duct is at low level. However, a plane flying within an elevated duct may have difficulty communicating with a plane outside the duct or with a distant ship because the duct may act as a barrier. When the temperature inversion and moisture lapse are very steep over a relatively thin layer of the atmosphere, radio waves may be reflected directly from the bottom of the duct. Under this condition, which probably will be encountered only rarely, the lower frequency radar and communications waves may be reflected repeatedly between the duct and the sea, and so carried long distances, even without trapping taking place. There will be skip distances associated with this type of propagation because the nature of the reflection is such that the waves are returned to earth only at intervals. If a plane is flying above a thin, sharply bounded duct of this type, it may be impossible for communications to be established between the plane and the ship. In rare cases, a phenomenon of this sort may also be responsible for failure of IFF. When communications from a plane fail, or the plane cannot make contact on a navigational aid, the pilot may be able to reestablish contact by changing altitude to get either above or below the duct.

When trapping causes echoes to be returned from targets at long ranges, the pips are likely to fluctuate far more than those from targets at short range. This fading is caused by changing propagation conditions within the duct. Such fading is of large amplitude, perhaps involving a change in echo power of as much as one-thousand-fold, and the echoes vary over a period of approximately 15 minutes. Violent fading of echoes appears to be a characteristic feature of trapping conditions that may aid the operator in realizing when such conditions exist.

If the water vapor content of the air increases with elevation, the radar waves are bent up instead of down. This condition, which is referred to as substandard, can exist in some kinds of fog or when fog is about to form. Although not enough is yet known about radar propagation in fogs to state its full effect, it appears likely that nearly all fogs produce substandard conditions. The obvious danger of this condition is that the fog prevents ordinary optical search, and at the same time reduces the radar detection range on surface vessels and low-flying aircraft. Unfortunately, there is very little that the operator can do to combat the effect of fog except to run his set at the greatest possible sensitivity.

Airplanes often fly very low to avoid detection by radar. However if a duct is formed near the surface of the water, such evasive action will probably be unsuccessful. If the

presence and height of the duct were known, better protection against radar detection would be furnished if the planes were to fly just above the top of the duct.

The changing propagation conditions that radar waves can encounter, then, can have considerable effect on radar performance. To summarize, the effect of trapping on a radar may be to:

(1) Increase the range of detection for airplanes flying within a duct.

(2) Reduce the range of detection for airplanes flying just above a duct.

(3) Reduce the range of detection for low-flying planes in some types of foggy weather.

(4) Modify the height at which airplanes should fly to avoid detection by enemy radar.

(5) Cause errors in height finding for targets below position angles of 1°.

(6) Increase the extent of clutter from sea return, and thus reduce the operational efficiency.

(7) Increase the range at which a navigational aid can be effective.

(8) Increase the range at which radar signals can be heard.

(9) Modify the degree of jamming either suffered or inflicted.

Weather effects cannot be blamed indiscriminately for variable performance of radar. In general, inadequate adjustment or incipient electrical failure will cause a far greater decrease in range than any variation in the propagation conditions. For example, failure to detect a high-flying airplane at short range cannot be attributed to nonstandard propagation; trapping affects the detection of targets only at low angles above the horizon.

c. Meteorological factors that cause trapping.—The atmospheric conditions which allow standard propagation to take place are common. The peculiar structure of the atmosphere that produces trapping, especially for frequencies of 3,000 megacycles and higher, also occurs fairly often in many parts of the world. Several types of meteorological conditions can produce the temperature and humidity gradients necessary for trapping to take place.

Warm continental air blowing over a cooler sea leads to the formation of a duct by causing a temperature inversion as well as by evaporation of water from the cooler sea into the lower levels of the warm dry air. The base of such a duct is usually the sea surface with the trapping region extending several hundred feet upward. At higher latitudes—above 25° or 30°—this type of trapping is most prevalent along the eastern shores of continents. If it is present in the lower latitudes, the duct will be formed on the western coasts. This distribution with latitude results from the normal direction of the wind, which must be off-shore to produce the effect. Ducts of this sort will form only when there is a distinct temperature difference between the sea and the air blowing from the land. Hence, conditions are most favorable for trapping in the summer months. The duct is usually from 500 to 600 feet high, and it tends to remain level for a distaince of 100 to 200 miles out to sea. Near the coast, trapping will be found to be strongest just after noon, and weakest just before dawn. Fog usually is not associated with the meteorological conditions that produce this form of trapping, but at times a surface fog will be observed 5 to 10 miles off shore.

Over the open ocean, a surface duct such as that in A or B, figure 2–20, may be formed by cool air blowing over a warmer sea. There is no temperature inversion associated with this phenomenon, and the entire effect is caused, apparently, by the evaporation of water into the lower levels of the atmosphere. Ducts of this sort are often created by easterly winds, such as the trade winds, that have blown for a long distance over the open sea. The height of the duct increases with the wind speed, and at the higher wind speeds typical of Pacific trade belt—10 to 20 knots—ducts 50 to 60 feet high occur quite generally. These ducts seldom attain the height and intensity necessary to entrap the lower frequencies, but S- and X-band radars that have antennas within the duct show better range performance for the detection of surface vessels and low-flying aircraft than can be predicted from consideration of the characteristics of the radar alone. These ducts are important because they extend for long distances.

An elevated duct as in C or D, figure 2–20, may form in an area of high barometric pressure

because of the sinking and lateral spreading of the air, which is termed "subsidence." When the air is warm and dry and the subsidence takes place over the sea, water is evaporated into the air, forming a moisture gradient that leads to the formation of a duct. Such ducts are always formed above the sea, with the base of the trapping layer ranging in elevation from a few thousand to 20,000 feet. Subsidence trapping can nearly always be found in the tropics; the ducts so produced usually are low and strong off the western coasts of continents in the trade winds latitudes, and high and weak near the equator. In areas where a monsoonal climate is found, subsidence trapping is weak or nonexistent in the moist, onshore, summer monsoon, and the duct is low and trapping strong during the dry, off-shore, winter monsoon. When a duct is formed as the result of subsidence, the strength of the trapping varies throughout the day, being weak in the midforenoon, and strong after sunset.

Other meteorological conditions that may produce trapping are cooling of land at night by radiation and the mixing of two masses of air, as at a warm or cold front. The ducts formed by these effects are likely to be of such limited extent that they are unable to modify radar propagation by any appreciable amount.

d. Prediction of non-Standard propagation.—In spite of the fact that the relation of weather to the production of trapping conditions is not fully understood, enough is known to permit a meteorologist to make a fairly reliable prediction. Considerable equipment is required to measure the several variables that must be known to determine the structure of the atmosphere, and rather specialized meteorological skills are needed to interpret the data. Since neither the skills, nor the equipment is generally available to the fleet, reliable predictions are diffcult to make on board ship. However, even in the absence of specialized equipment and personnel, it may sometimes be possible to predict the formation of ducts from observation of weather conditions, coupled with simple measurements that can be made on board any ship. Such an estimate cannot hope to be highly reliable at present, but continuing research on the problem may ultimately reveal a fairly simple

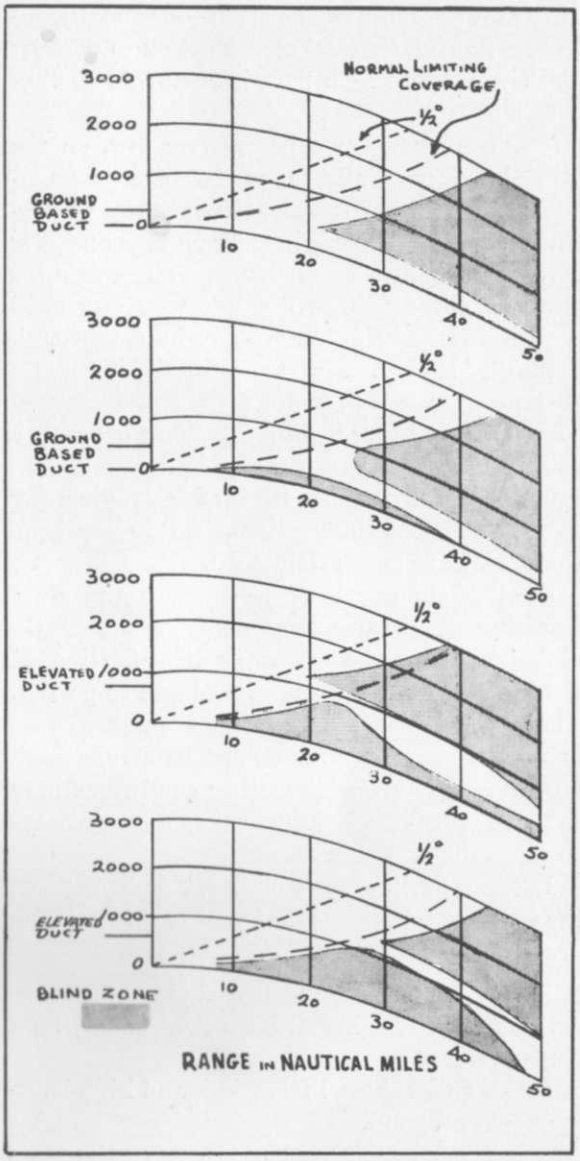


Figure 2–20.—Coverage diagram showing the existence of ground-based and elevated ducts.

relationship between weather and trapping that will allow propagation conditions to be evaluated routinely.

For a number of reasons the meteorological conditions in a region of high barometric pressure are favorable for the formation of ducts. Among the favorable factors are: subsidence, which creates temperature inversions, and which occurs in areas where the air is very dry so that evaporation can take place from the surface of the sea; calm conditions that prevent mixing

of the lower layers of the atmosphere by turbulence, allowing thermal stratification to persist; and clear skies which permit nocturnal cooling over land.

The conditions in a barometric low, on the other hand, generally favor standard propagation. A lifting of the air, the opposite of subsidence, usually occurs in such regions and it is accompanied by strong winds. The combined effect of these factors is to destroy any local stratification of the atmosphere by a thorough mixing of the air. Moreover, the sky is usually overcast in a low-pressure area, and nocturnal cooling is therefore negligible. Very often rain falls in a low-pressure area, and the falling drops of water have the effect of destroying any nonstandard humidity or temperature gradients that may have been established.

In all of the weather conditions that produce trapping, the atmosphere must be sufficiently stable to allow the necessary stratification of the atmosphere to be established and to persist. Thus, continued calm weather or moderate breezes are necessary. It must be emphasized, however, that even if weather conditions may favor the formation of ducts, they do not always produce them.

In terms of the readily observable phenomena, the weather conditions that may favor trapping are:

(1) A moderate breeze that is warmer than the water, blowing from a continental land mass.

(2) Clear skies, little wind, and high barometric pressure.

(3) A cool breeze blowing over the open ocean far from large land masses, especially in the tropical trade wind belt.

(4) Smoke, haze, or dust that fails to rise, but spreads out horizontally, indicating quiet air in which a temperature inversion may exist.

(5) When the air temperature at bridge level on a ship definitely exceeds that of the sea, or when the moisture content of the air at bridge level is considerably less than that just above the water, and the air is relatively calm.

Although trapping conditions can occur at any place in the word, the climate and weather in some areas make their occurrence more likely. In some parts of the world, particularly those possessing a monsoonal type of climate, variation in the degree of trapping is mainly seasonal, and enormous fluctuations from day to day may not occur. In other parts of the world, especially those in which low barometric pressure areas recur often, the extent of nonstandard propagation conditions varies considerably from day to day, even during the season of greatest prevalence.

Even though the geographical and seasonal aspects of trapping are not yet so firmly established that a map of the world can be drawn with trapping areas reliably delineated, it is possible to make a general summary.

(1) *Atlantic coast of the United States.*—Along the northern part of this coast, trapping is common in summer, while in the Florida region the seasonal trend is the reverse, with a maximum in the winter season.

(2) *Western Europe.*—On the eastern side of the Atlantic, around the British Isles and in the North Sea, there is a pronounced maximum of trapping conditions in the summer months.

(3) *Mediterranean region.*—Available reports indicate that the seasonal variation is very marked, with trapping more or less the rule in summer, while conditions are approximately standard in winter. Trapping in the central Mediterranean area is caused by flow of warm dry air from the south (sirocco) which moves across the sea and thus provides an excellent opportunity for the formation of ducts. In the wintertime, however, the climate in the central Mediterranean is more or less a reflection of Atlantic conditions and hence it is not favorable for duct formation.

(4) *The Arabian Sea.*—The dominating meteorological factor in this region is the southwest monsoon that blows from early June to mid-September and covers the whole Arabian Sea with moist equatorial air up to considerable heights. When this meteorological situation is fully developed, no occurrence of trapping is to be expected. During the dry season, on the other hand, conditions are very different. Trapping is then the rule rather than the exception, and on some occasions extremely long

ranges, up to 1,500 miles, have been observed on P-band radar on fixed echoes.

When the southwest monsoon sets in early in June, trapping disappears on the Indian side of the Arabian Sea. However, along the western coasts, conditions favoring trapping may still linger. The Strait of Hormuz is particularly interesting as the monsoon there has to contend against the shamal from the north. The strait itself lies at the boundary between the two wind systems, and a front is formed with the warm, dry shamal on top and the colder, humid monsoon underneath. As a consequence, conditions are favorable to the formation of an extensive duct which is of great importance to radar operation in the Strait of Hormuz.

(5) *The Bay of Bengal.*—The seasonal trend of trapping conditions is the same as in the Arabian Sea, with standard conditions occurring during the summer southwest monsoon, while trapping is found during the dry season.

(6) *The Pacific Ocean.*—This region appears to be one where, up to the present, least precise knowledge is available. However, there seems to be definite evidence of the frequent occurrence of trapping around Guadalcanal, the east coast of Australia, and around New Guinea. Observations along the Pacific coast of the United States indicate frequent occurrence of trapping, but no clear indication of its seasonal trend is available. The meteorological conditions in the Yellow Sea and the Sea of Japan, including the island of Honshu, are approximately like those off the northeastern coast of the United States. Therefore, trapping in this area should be common in the summer. Conditions in the South China Sea approximate those off the southeastern coast of the United States only during the winter months, when trapping can be expected. During the rest of the year, the Asiatic monsoon modifies the climate in this area and no data are available as to the prevalence of trapping during this time. The trade winds in the Pacific lead to the formation of rather low ducts quite generally over the open ocean.

6. *Weather.*—Since moisture has substance, and hence reflects radio-frequency energy, the radio-frequency pulses of a radar beam are capable of detecting the presence of rain, or dense, electrically charged clouds. The image as presented on a scope appears as a strongly illuminated area of irregular shape.

The intensity of cloud echoes as indicated by a radar set depends upon:

(a) The total amount of visible water per unit volume of the atmosphere.
(b) The size of the water droplets.
(c) The frequency of the radar set.

a. General.—(1) The relationship of the intensity of a cloud echo to the intensity or development of the meteorological condition is at present known only qualitatively.

(2) When cloud formation is used simultaneously with the current synoptic information

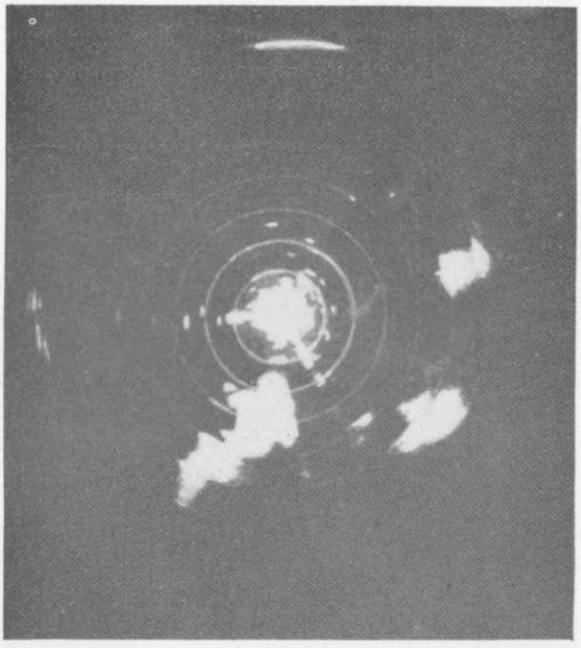


Figure 2–21.—Radar echo from thunderstorm of the convective type shown on the PPI. Radar is adjusted for 40-mile range and concentric lines are 5-mile markers. Irregular bright area at azimuth 190 and 20-mile range is thunderstorm. Note bright, solid appearance of echo and distinct boundary. Thunderstorms may often be identified as such by tipping parabola upward and scanning in elevation to disclose vertical structure of area from which echo is coming. This is readily computed from range and elevation angle data. In this case scanning in elevation disclosed a vertical extent of this storm of 40,000 feet, probably exaggerated to some extent by the beam width. Summer thunderstorms, however, give radar echoes to great heights in the atmosphere, thus readily distinguishing them from echoes from cumulus congestus clouds and other phenomena.

of the same area, an estimate may be made of the conditions aloft. For tactical purposes, aircraft may be directed to avoid weather conditions hazardous to flight operations within the range of the set. In many cases a check is available on the development of storm conditions.

b. Identification of thunderstorms.—(1) The echo of a thunderstorm is one of the most easily identified signals detected. When examined on the PPI, it appears as a bright, dense, central area with indistinct boundaries. Because of the vertical extent of thunderstorms, the cloud echo will be indicated at higher elevation angles than targets at the same range. The maximum angle of elevation at which the cloud echo is received and the distance is a rough measure of the height or vertical structure of the thunderstorm.

(2) Air mass or convective thunderstorms are scattered in a random manner; the area covered by an individual thunderstorm is usually of the order of several square miles. This type storm moves with the velocity and direction of the general circulation.

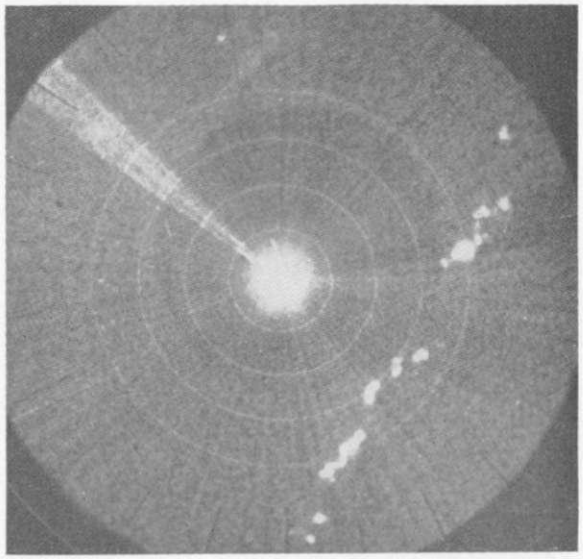


Figure 2–22.—PPI presentation of radar echoes from cold-front thunderstorms. Radar is adjusted to 100-mile range. Range markers are at 20-mile intervals; 80-mile marker is farthest visible. Cold-front thunderstorms appear as line of bright echoes in northwest quadrant. Note ready distinction from irregular distribution of convective type of thunderstorm shown in figure 2–21. Radar was located at Cambridge, Mass., and photo was taken July 22, 1943, at 5 p. m. Because storm echoes may be seen so much farther than normal land targets (due to their great vertical development) it is important to search from time to time with the long-range adjustment of the system in order to pick up the echo at the earliest possible moment.

(3) Orographic thunderstorms are generally characteristic of the terrain for certain atmospheric conditions. This type of thunderstorm will usually show little movement.

(4) Cold-front thunderstorms are usually arranged in a line and bear a marked resemblance to the frontal system. Warm-front thunderstorms may be scattered or they may form along a line.

c. Identification of frontal conditions—(1) *General.*—Frontal conditions are generally accompanied by thunderstorms, rain showers, rain, and various cloud systems. The greatest concentration of activity is usually located in the frontal zone.

(2) *Cold fronts.*—An active cold front is easily located as a line of cloud echoes. The structure and activity of cold fronts can be estimated qualitatively by consideration of the intensity of the cloud echoes, spacing between areas of brightness, the area covered by each cloud, the vertical extent and the velocity of the front. Weak cold fronts are often poorly defined and may be missed entirely.

(3) *Warm fronts.*—Echoes from warm fronts are extremely variable. Atmospheric conditions (thunderstorms, showers, general precipitation, etc.) associated with warm fronts usually cover a wide area. Occasionally these conditions are concentrated in the active frontal zone; however, the majority of cloud echoes from warm-frontal conditions will be hazy and will cover extensive areas of the order of hundreds of square miles.

(4) *Equatorial front.*—Echoes reported from the equatorial front may have the characteristics of cold fronts or warm fronts or a combination of both.

d. Identification of other atmospheric echoes—(1) *Line squalls.*—The cloud echo of a line squall will appear as a long, narrow, rapidly moving thunderstorm (fig. 2–23).

(2) *Showers.*—Echoes received from showers are generally less intense than thounderstorm echoes and have a hazy structure. The central portion is not always of the greatest intensity.

Cloud echoes have been reported when no precipitation was reaching the ground in the area of the cloud echoes. It is still uncertain as to the reasons why cloud echoes received from certain atmospheric conditions are not received again under an apparently similar set of atmospheric conditions at another time.

B. Constant factors. Regardless of the type of radar, there are certain "constant" factors which limit performance or impair to some extent the correct interpretation of screen patterns:

1. *Power.*—Power output from airplane generators, limitations of space, and the weight that can be carried by different types of aircraft affect the radiation power of air-borne radar and, in consequence, determine to a large extent the maximum ranges which can be attained.

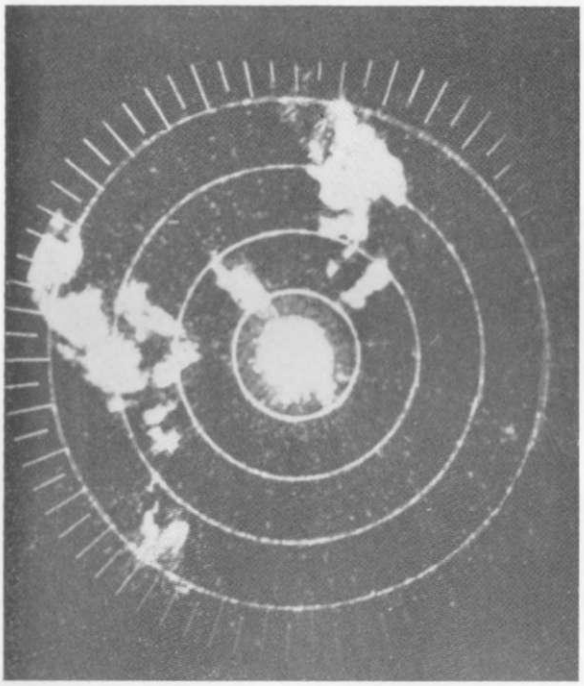


Figure 2–23.—Radar echo from precipitation in cumulus congestus clouds. System is adjusted for 20-mile range and markers show 4-mile intervals. It is noted that appearance on PPI is similar to thunderstorm echo. Distinction is made by scanning elevation. In this case it was disclosed that vertical development extended to only 15,000 feet. The meteorologist can thus get a valuable hint as to lapse rate aloft and vertical extent of instability by scanning in cross section through cloud areas. While no precipitation may reach the ground in some of these cases the area would undoubtedly be a poor one to fly through with aircraft. Few land targets are seen on the scope because the beam is elevated above the horizon.

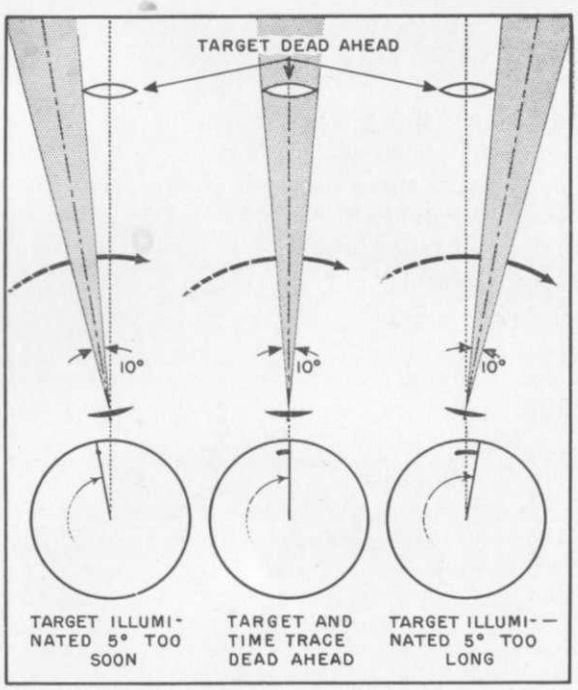


Figure 2–24.—The size of the target on the scope is no reliable indication of relative target size. This diagram shows how the beam width tends to distort target size (length).

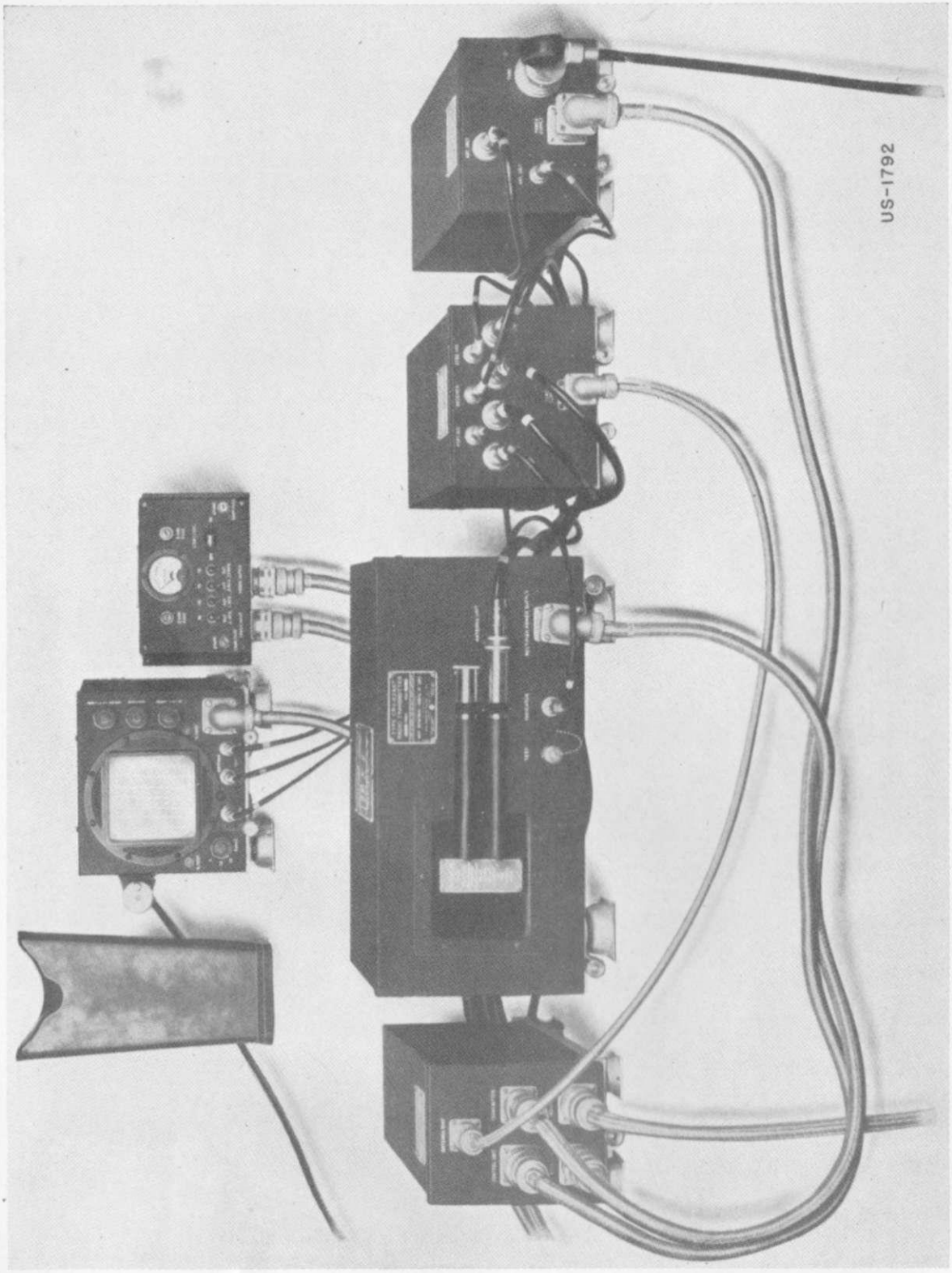
2. *Beam width versus trace width.*—The width of the radar beam varies from about one-half of one degree in some equipments to as much as 30 degrees in others. The time trace on the map-type radars is a fine sweep line which denotes the orientation of the antenna in azimuth with respect to dead ahead. Also, it represents a center line through the radar beam. However, echoes from any target *lying within the beam width* of the radar will register on the time trace. Thus, if a beam is, for example, 10° wide, the leading edge of the 10° beam will cause an intensification 5° too soon on the rotating time trace; likewise, the trailing edge of the beam will cause retention of the intensification 5° too long. See figure 2–24. The result is an elongated indication on the scope, giving the impression that the target is of greater length than is actually the case. This effect varies with range.

3. *Range resolution and diffusion of light.*—Depending on the angle at which a radar beam strikes a target, the apparent size of an object

on map-type presentations is increased by a diffused fringe of light which surrounds the scope presentation of all targets. On the 20-mile scale, this extra illumination will cause an error of about one-tenth nautical mile. The cumulative effect of these errors results in a slight apparent increase in the dimensions of land and other targets, and thus partially obscures certain identifying characteristics of size, shape and depth. In some cases, this diffusion is sufficient to mask or fill in scope images of channels and rivers. The condition, however, can be cleared up considerably by the intelligent manipulation of the tilt control of the antenna spinner.

None of the above factors seriously affects the accurate computation of range and does not attain major importance unless the radar is to be used to bomb cities and islands where sharp definition is necessary for the selection of the proper targets. Greater definition has been attained in the newer equipments by the use of a narrow beam width, a short pulse length, and operation within the microwave frequencies.

4. *Maintenance.*—Probably the most important factor which limits the ability of any piece of electronic gear to function at top efficiency is the level of systematic maintenance which the system receives. The regularity with which preflight and other periodic performance checks are made will do much to insure that not only are the maximum number of available airborne electronic installations functioning but that each one is operating at a degree of efficiency which will allow tactical commanders to expect the maximum in performance.



ASB

ASB SERIES

NOTE:—These equipments were designed and manufactured prior to the adoption of the "AN" nomenclature system and continue to bear the older, Navy ASB designation. ASB–1, –2, –3, –4, and Bendix receivers for ASB–5 (Serials 1 through 207) are obsolete.

It is expected that ASB installations ultimately will be replaced by AN/APS–4.

I. FUNCTION

A. PRIMARY PURPOSE. ASB is low-powered type of L-band air-borne radar intended primarily for search use.

B. SECONDARY USES. Although designed specifically to operate as a search radar, ASB through its long period of use has lent itself admirably to such applications as navigation, beacon homing, low-altitude bombing, and IFF (target identification).

II. DESCRIPTION

A. MAIN COMPONENTS. The units comprising the ASB system are:

1. Movable, directive antennas.
2. Hydraulic antenna controls.
3. Low-powered transmitter.
4. Receiver.
5. Antenna switching system.
6. Indicator.
7. Control unit.
8. Power supply, cables, junction boxes.

Two Yagi, or "fishbone," antennas are provided, usually mounted under the port and starboard wing tips (see fig. 2–25), or on the port and starboard sides of the hull. At the operator's position are located the hydraulic antenna controls, the receiver, indicator, and the control box units. Generally, all other units are situated in a remote location in the aircraft since they require no continuous manipulation or adjustment during operation.

B. ANTENNA SCAN AND SCOPE PRESENTATION. 1. *Beam coverage and antenna control.*—Each of the antennas emits radio energy in a beam or lobe approximately 40° wide in the horizontal plane. In the vertical plane the beam is approximately 45° in depth when the antennas are in the homing position and about half that depth when in the search position.

By means of separate hydraulic controls, one for each antenna, the antennas can be moved together or independently, from ahead outboard through an arc of about 90° (see fig. 2–26). A notched arrangement of the control mechanism allows the antennas to be moved through their train in 8° steps.

When the hydraulic controls are fully retarded, the antennas point outboard to port and starboard, at right angles to the line of flight (search position). When moved to their full forward position the antennas point dead ahead (homing position). Intermediate positions of the antennas may be judged by observing the positions of the antenna control handles.

2. *L-scan.*—The scope in the ASB indicator is the L-type (see fig. 2–27), where range is indicated by the position of blips upward from the bottom of the vertical time trace. Bearing is

Figure 2–25.—The ASB antennas are mounted under the wing tips on the TBF aircraft.

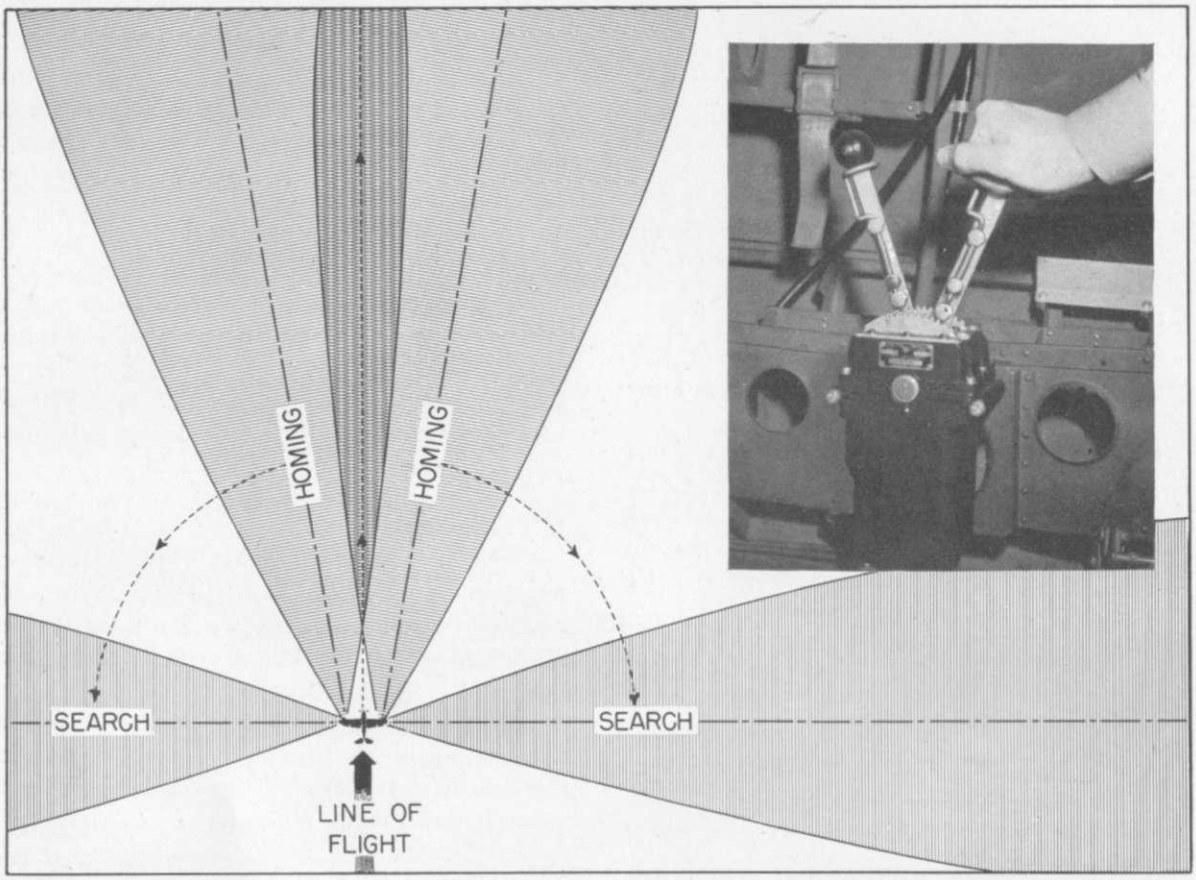


Figure 2–26.—Manually operated hydraulic controls permit the wing tip antennas to be rotated in steps from the homing position dead ahead, outboard to the search position. The antennas may be moved singly or together.

indicated by the lateral disposition of the blips about the trace.

The width of the beam is such that in the full forward position an overlap of both antenna beams is produced; from targets dead ahead, then, each antenna receives an equal amount of reflected energy and so produces a blip equally spaced laterally on the trace. Targets slightly off to either side of dead ahead will produce a blip whose sides are of unequal length and so indicates their bearing. Echoes from port or starboard targets are indicated on the scope as blips on the port or starboard sides of the trace only when one or the other of the antennas has been moved sufficiently to place its beam on the target.

A single target such as a ship, aircraft, or buoy will produce a single blip on the trace, its

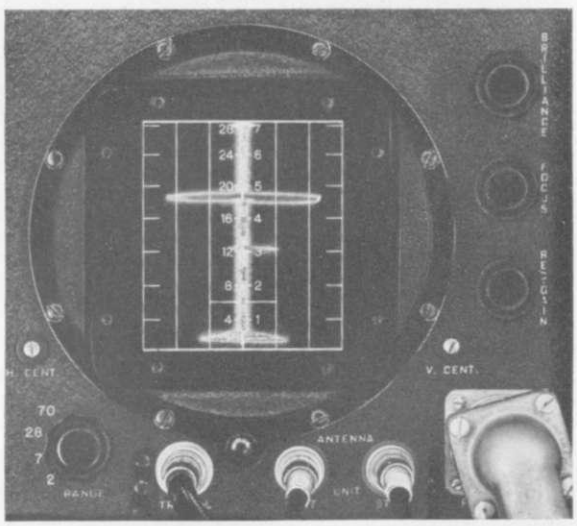


Figure 2–27.—When the "gain" or sensitivity of the receiver is increased, electrical and atmospheric noise causes an irregular indication (grass) along the length of the trace. A large target is indicated at about 4¾ miles and a small target to starboard at 3 miles. The height of the lower edge of the sea return furnishes a rough indication of the aircraft's altitude.

lateral length affording some indication of its relative size. Land targets, ship convoys, or closely grouped islands, because they return many echoes, produce many blips closely bunched together.

Stray radiation of radio energy from the antennas to the sea or terrain directly below the aircraft returns echoes of considerable strength. They appear on the scope screen as irregular blips near the bottom of the trace. This irregular scope pattern is called the sea return (or ground return). The distance upward from the bottom of the trace to the bottom of the sea return is a measure of the aircraft's absolute altitude.

3. *Range settings.*—Four operating ranges are provided—2, 7, 28, and 70 nautical miles. A graduated plastic scale placed over the face of the scope enables the operator to judge target ranges with a fair degree of accuracy for the 7-, 28-, and 70-mile ranges. On the 2-mile setting, ranges must be approximated.

C. Improvements incorporated in later ASG equipments. Long standard for carrier-based aircraft, the ASB radar was continued in use for some aircraft types because of a series of improvements which enabled it to meet the demands of the fleet. Greater security, longer ranges, increased accuracy, and ability to carry out varied tactical assignments were made possible with the later ASB equipments.

1. *Frequency changes.*—Because of ASB's comparatively low frequency, enemy jamming attempts have been feared more with ASB than with more modern microwave equipments. To assist in avoiding such action by the enemy, improved transmitters have been designed to operate at any of three different frequencies instead of only one as was formerly the case. This group of three frequencies are referred to as "A_1," "A_2," and "A_3." A change from one frequency to another cannot be made in flight, chiefly because antenna adjustments are necessary; however, a change between flights is easily accomplished and different aircraft in a squadron may operate on different frequencies.

2. *Main components.*—The ASB radars equipped for "A"-band operation include two new units: The ASB-7A indicator, which is a complete redesign, and the ASB–7A (or ASB–7B) transmitter. The ASB–7A transmitter is simply the ASB–7 transmitter modified to be tuneable over the "A" band. The ASB–7B transmitter is the redesigned, high-power, plate-pulsed unit. In addition, the complete radar set includes the ASB–7 or ASB–Series receiver of the type already in use, which is capable of being tuned to any of the "A" band frequencies, the ASB–7 control unit, rectifier power unit and antenna switching unit.

3. *Sensitivity switch.*—In addition to "A"-band operation, a second safeguard against enemy jamming is the sensitivity switch, mentioned above, for the receiver. The switch is designed to prevent saturation of the receiver by jamming signals.

4. *Special features and advantages of the new* ASB.—Installations using the new ASB–7B transmitter and the ASB–7A indicator have, in addition to greater security, several other advantages. The ASB–7B transmitter more than doubles the power output of the ASB–7 or ASB–7A transmitter—approximately 8 to 10 kilowatts (peak power) as compared to 3 to 5 kilowatts. This power increase accounts for 30 to 40 percent increase in range results. Also, the ASB–7B transmitter has been designed to

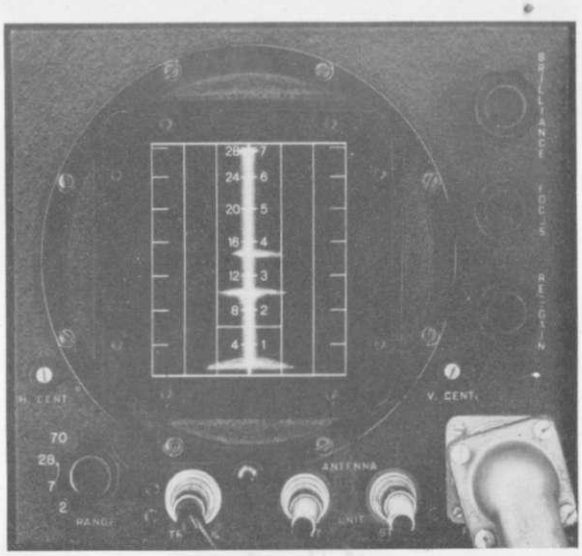


Figure 2–28.—On the 28-mile range two single-ship targets appear—one at 15 miles, the other at about 11 miles. With the antennas in the homing position the near target is almost dead ahead while the farther one is slightly off to the starboard side of dead ahead.

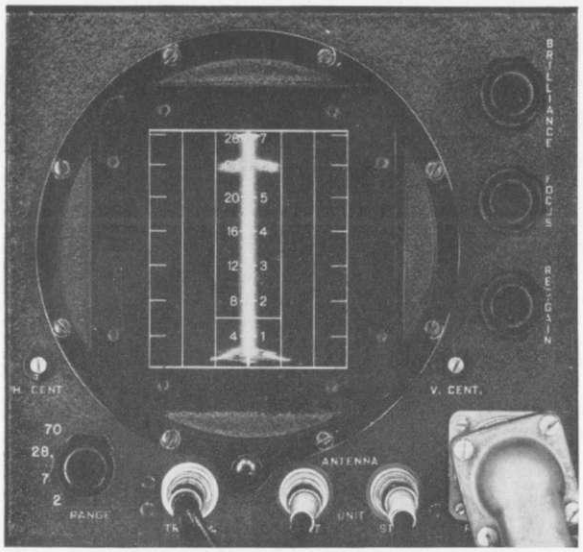


Figure 2–29.—A beam-on approach to ships in convoy might produce the blip shown above. It shows several target blips closely grouped at about 24 miles.

give low "case radiation" so that interference affecting radio reception is reduced.

Still other advantages in performance, operation and maintenance are provided by the new ASB–7A indicator. Among them are:

(*a*) More accurate indication of target ranges.

(*b*) New range scales fitting the ASB for the tactical demands of present-day carrier-based aircraft; a 150-mile range with 30-mile calibration intervals; a 50-mile range with 10-mile calibration intervals; a 15-mile range with 3-mile calibration intervals; a 5,000-yard range with 1,000-yard calibration intervals, and additional 200-yard intervals between zero and 2,000 yards (provided for torpedo runs and bombing).

(*c*) Provisions for operating ASB with AN/APA–16 (low altitude bombing equipment).

(*d*) Circuits which maintain substantially optimum focus and stable operation on all ranges.

(*e*) Addition of front-panel controls to compensate for effects of generator voltage and wave-form variations.

(*f*) Triggering from leading edge of pulse, eliminating the "inherent error" of former indicators.

III. TACTICAL EMPLOYMENT

A. Search. 1. *Types of targets.*—In the PPI-type (and to some extent, the B-type) scope presentations, targets are displayed in their true azimuth and range relation to the searching aircraft. Coastal areas, islands, harbors, rivers and large lakes are shown in maplike form. But in equipments such as the ASB which employ the L-type scope presentation, all targets are represented by blips—or the absence of blips. Reading the L-type scope pattern requires the mental facility of converting blips of all shapes and sizes and numbers into a mind picture of the types of target they represent.

With the exception of the sea return caused by the return of echoes from the sea directly below the plane, sea areas generally return no echoes. So, when flying over water areas there is an absence of blips on the trace. (The exception to this is when a relatively rough sea surface causes waves high enough to return echoes.)

Conversely, land masses return many echoes, their strength and number varying with relation to the topography of the terrain, the range at which they are received, and the sensitivity (or "gain" setting) of the receiver. The depth of a land mass can be ascertained by the amount of trace covered by the blips.

Single ship targets, figure 2–28, produce single blips, but their size and depth on the trace cannot be relied upon to indicate the relative

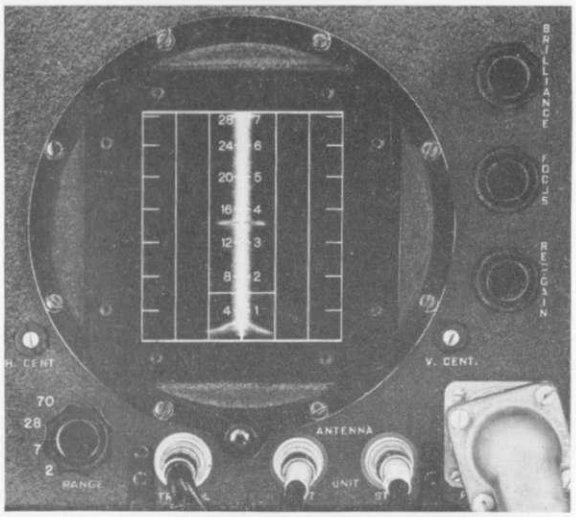


Figure 2–30.—On the 7-mile range an aircraft target lies dead ahead at about 3½ miles.

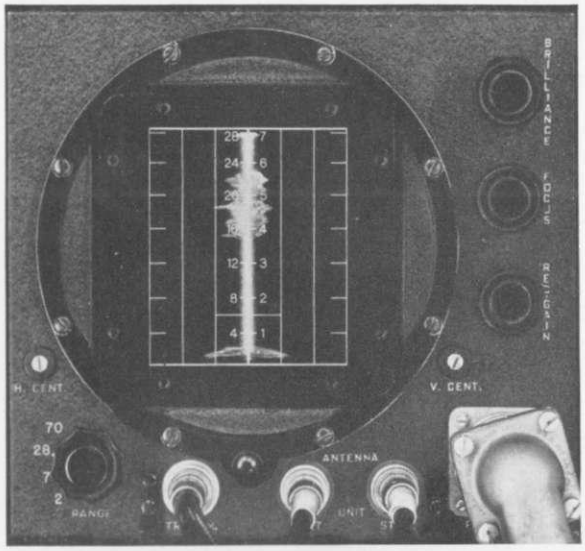


Figure 2–31.—This irregular long blip is caused by reflections from an island dead ahead.

size of the target, for the area and composition of the reflecting surface offered by the target to the beamed energy determines the strength and size of the blip. A small ship broadside may produce a blip as large and as strong as a large ship bow-on.

Ship convoys, figure 2–29, produce many blips in a small area on the trace but each ship blip is usually individually distinct because of the sea area separting the ships. Small islands and projecting strips of land, however, return one large blip (consisting of many small blips) having a jagged and irregular outline.

Single aircraft target blips, figure 2–30, have the same general characteristics as a single ship blip excepting that, because of the changing attitude presented by an aircraft in flight, its blip will "beat" or pulsate. Aircraft blips can be recognized by their relatively faster movement up or down the trace, or their complete lack of movement. An aircraft on a reciprocal course to the search aircraft will produce a blip which moves down the trace rapidly. The range to an aircraft on the same course, ahead, will be closed less rapidly than for a ship target. If the speed of the two aircraft is identical, the target blip will remain in one position for a long period of time.

2. *Wind (or drift) pattern.*—High surface winds cause otherwise calm seas to become rough, resulting in an increase in the reflecting area of the sea surface in certain directions and causing an increase in the sea return. In general, the sea return rises highest on the trace when the antenna is pointing toward the wind and is less when the antenna is pointing downwind. Winds of 15 knots or better can be checked in this manner, from altitudes of 1,500 feet and below.

3. *Altitude ranges.*—ASB is not designed for high-altitude operation, works less efficiently above 10,000 feet, and is subject to electrical breakdown at higher altitudes. The best altitudes for search with ASB are approximately 6,000 feet and below.

The table below presents a general performance indication of the equipment for various kinds of targets.

Type of Target:	*Average detection range (miles) (1,800 feet altitude)*
Mountainous terrain	50–60
Coastal rolling hills	35–45
Small, flat islands	15–20
Task force, convoy	35–50
Single capital ship	25–35
Vessel, 10,000 tons	20–25
DE, PC boat	10–15
Wooden escort vessel	7–10
Submarine, surfaced or with conning tower awash	5–10
Aircraft	4–5

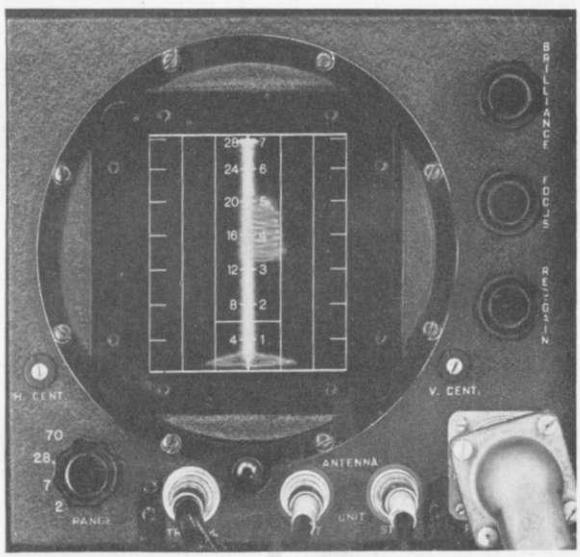


Figure 2–32.—With the starboard antenna pointed 90° to starboard an island blip appears at about 13 miles. The height of the blip on the trace generally denotes the depth of the island.

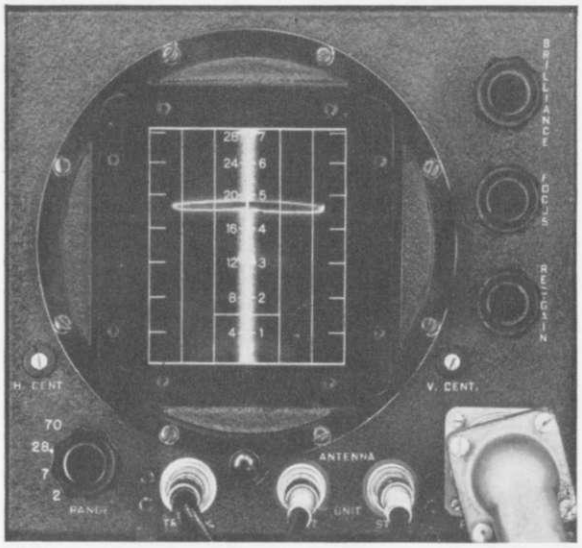


Figure 2–33.—With the ASB receiver tuned to the YJ beacon frequency a strong coded beacon signal shows at about 18 miles.

B. Navigation. Radar navigation with ASB means, primarily, identifying with respect to range and azimuth position the characteristic blips of coast lines, strings of islands, harbors or other recognizable terrain contour features and comparing this information with charts of the area for the purpose of making landfalls, guiding a flight through channels, returning to a base or homing on a specific target.

1. *Homing: Radar targets.*—Movements of the antennas for search purposes through their 90° arc makes it possible to pick up coast-line promontories, harbors or islands (see figs. 2–31 and 2–32). After a target has been identified by reference to its known geographical, charted location, the aircraft's heading is altered to home on it and the antennas are swung to the dead-ahead, or homing, position.

Drift can be approximated to a fairly accurate degree by observing the direction of the antenna when a high sea return on one side of the trace is produced (See "Wind (or Drift) Pattern," p. 37). Actual ground speed can be estimated by observing over a measured period of time the movement of the target blip down the trace. Knowing these factors, a collision course can be developed for homing on the selected target.

2. *Homing: Beacon targets.*—Radar beacon homing, although requiring that all of the factors as in the case of target homing be known, is made easier of accomplishment for the following reasons:

(*a*) Greater homing accuracy results because, instead of homing on an indefinite and sometimes only generally identifiable radar target, the radar receiver, tuned to a radar beacon frequency, receives a coded, definitely identifiable signal from a beacon transmitter whose actual location is a matter of previous knowledge.

(*b*) Instead of being a weak, reflected radar echo, the radar beacon signal is a relatively powerful transmitted signal and can be observed at much greater ranges.

(*c*) Retuning a radar receiver to a radar beacon transmitter frequency clears the scope screen of echo blips. Thus, radar beacon signals, if the beacon is within range, appear sharply and distinctly on the scope screen, correct in range, and, when the antennas are in the forward or homing position, correct in relative hearing. (See figs. 2–33 and 2–34.)

Identity of radar beacon stations is established by observing the coded sequence of the signal blips as they appear on the scope screen.

C. Bombing or torpedo dropping. 1. *Fac-*

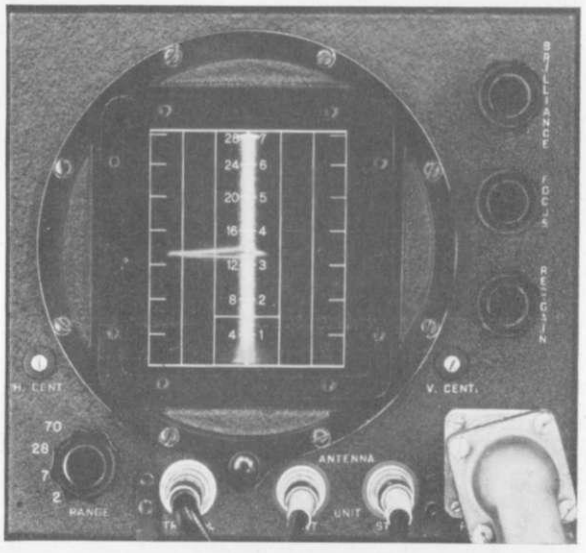


Figure 2–34.—Same target as in figure 2–33. Range is closed slightly. The displacement of the blip toward the left of the trace indicates that the search aircraft has changed bearing slightly to starboard.

tors to be determined.—Bombing with ASB presupposes that a definite target has been selected and homed on and that the range has been closed sufficiently to permit use of the 2-mile range scale. As explained previously for the homing techinques, drift and speed must be determined and taken into account when making a bombing run.

In making a bombing run, observation of the target blip's lateral position on the trace can be improved immeasurably if as the range is closed the two antennas are moved simultaneously a few notches outboard from the homing or full forward position. This procedure narrows the overlap area of the two antenna lobes ahead of the aircraft. Then, even a slight deviation of the aircraft from the true homing course will be apparent from the rapid movement of the blip either side of the trace.

2. *Release point.*—In general, the greater the altitude, the more difficult it is to home directly over a target. Therefore, in order to reach the release point, bombing with ASB calls for low-altitude homing on a specified target with a high degree of accuracy right down to the last few hundred yards.

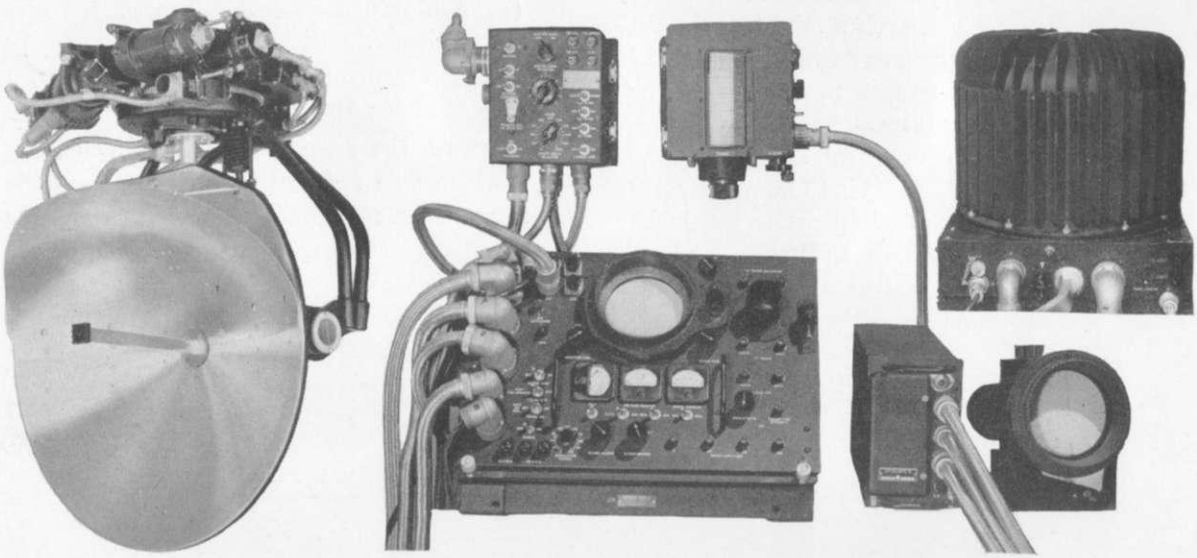
The bomb release point is determined from a reference point called the "mergence point" which on the ASB indicator is a noticeable change in the appearance of the target blip at a range of about 500 yards. The actual release point may be at the mergence of the target echo with the top of the sea return or it may be at a point obtained by a timing count from its first appearance.

On the 2-mile scale, certain features of sea return display must be kept in mind when determining the release point:

(*a*) Sea return is a function of the aircraft's altitude.

(*b*) Sea return tends to mask the blip of a target at close range.

Therefore, the sensitivity or "gain" of the receiver must be reduced in order to keep the sea return at a minimum (and to prevent the target blip, at close range, from reaching the saturation point).



AN/APS-15

AN/APS–15

I. FUNCTION

A. Primary purpose. AN/APS–15 is an X-band radar designed primarily for general search operations in heavy patrol craft.

B. Secondary uses. AN/APS–15 may be employed for navigation, beacon homing, and pattern bombing. In conjunction with other electronic equipment, it may be used for target identification.

II. DESCRIPTION

A. Main components. The main units of AN/APS–15 are:

1. Transmitter-converter unit.
2. Rotating antenna-spinner assembly.
3. Receiver-indicator, housing the operator's viewing (PPI) and monitoring (A) scopes.
4. Repeater (PRI) scope, for pilot or navigator use.
5. Computer box.
6. Control unit.

The computer box and control unit are mounted adjacent to the receiver-indicator, convenient to the operator.

The antenna-spinner assembly, together with the transmitter-converter, is housed in a plastic radome to protect it in flight in its rotation through 360° of azimuth. In some installations this entire assembly is mounted on a platform within the aircraft and must be lowered through the fuselage prior to operation of the equipment.

B. Antenna scan and scope presentation. 1. *Beam coverage.*—The rotating antenna projects a beam or lobe of radio energy, outward and downward, 3° wide in azimuth and extending in a vertical plane from a few degrees below the horizontal to about 10° forward of the vertical axis of the aircraft. See figure 2–35.

The extent of the area covered by the rotating beam depends mainly upon the altitude of the aircraft in which AN/APS–15 is installed. (See Tilt, p. 43, par. 2.)

2. *PPI-scan.*—On both the PPI and PRI scopes, a radial time trace revolves in step with the rotating antenna. Targets in the scanned area return echoes which cause bright spots to appear on the time trace, leaving their mark on the scope screen, correct in azimuth and range. Surface ships and aircraft produce relatively small light spots on the screen. Islands, coast lines, and large land masses produce relatively large patches of light having a maplike quality, their outlines being generally similar to the actual outlines of the terrain scanned by the antenna beam. Because of the peculiarly shaped antenna radiation pattern, large targets,

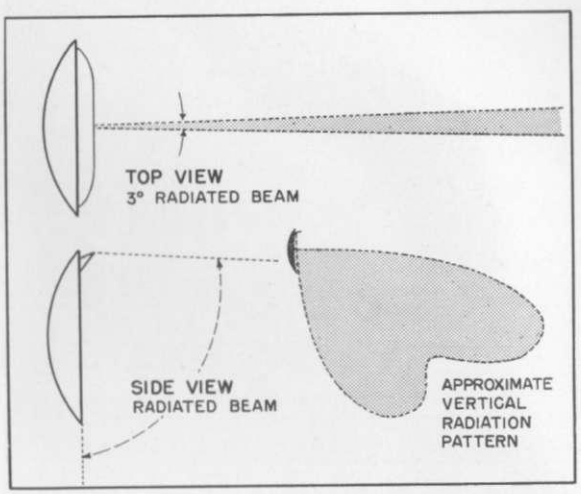


Figure 2–35.—Looking down from the top the beam emitted from the antenna spinner is 3° wide. Viewed in a vertical plane, the radiation pattern of the beam, unlike in other types of PPI equipment, is made purposely wide to cover a large area forward to the horizon and downward.

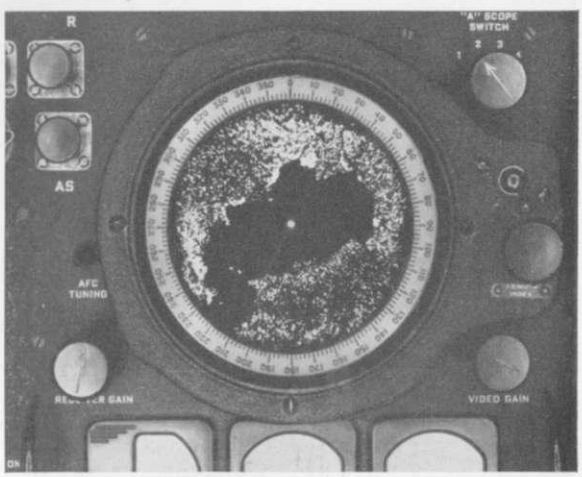


Figure 2–36.—The relief map quality of a land mass pattern such as that shown above is characteristic of the scope presentation of APS–15. This view shows the Tokyo Bay area. Note the heavy concentration of bright spots indicating city areas.

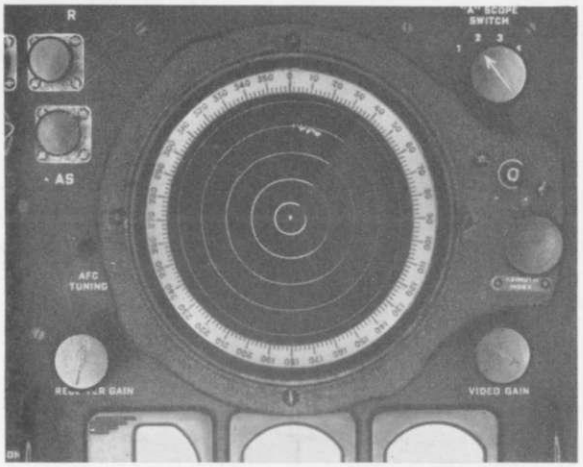


Figure 2–37——Range marks on the APS–15 scope appear as circles of light. This view shows the circles produced when the equipment is set to the 50-mile range. Note the convoy just inside the 40-mile circle at a bearing of 10°.

particularly land masses, produce scope images with a fidelity which compares favorably with a relief map of the region. See figure 2–36.

3. *Range settings.*—At calibrated intervals along the trace, bright spots can be made to appear, which, as the trace rotates, produce evenly spaced circles on the scope screen. These circles or range marks assist in judging approximate target ranges. See figure 2–37.

Four operating ranges are provided—5, 20, 50, and 100 miles.

Ranges	*Number of range marks*	*Interval between range marks*
5	5	1 mile
20	4	5 miles
50	5	10 miles
100	5	20 miles

C. Special features. AN/APS–15 incorporates in its design certain special features which increase the effectiveness of its use for search, navigation, and pattern bombing. They are:

1. Open center control.
2. Antenna tilt.
3. Automatic tilt stabilization.
4. Automatic azimuth stabilization.
5. Manual sector scan.
6. Automatic sector scan.
7. Electronic lubber line.
8. Altitude determination.
9. Drift determination.
10. Precision ranging.
11. Sweep delay selector.
12. Beacon homing.

1. *Open center control.*—At close ranges (5 to 20 miles), targets around the center of the screen may be somewhat crowded. In order to

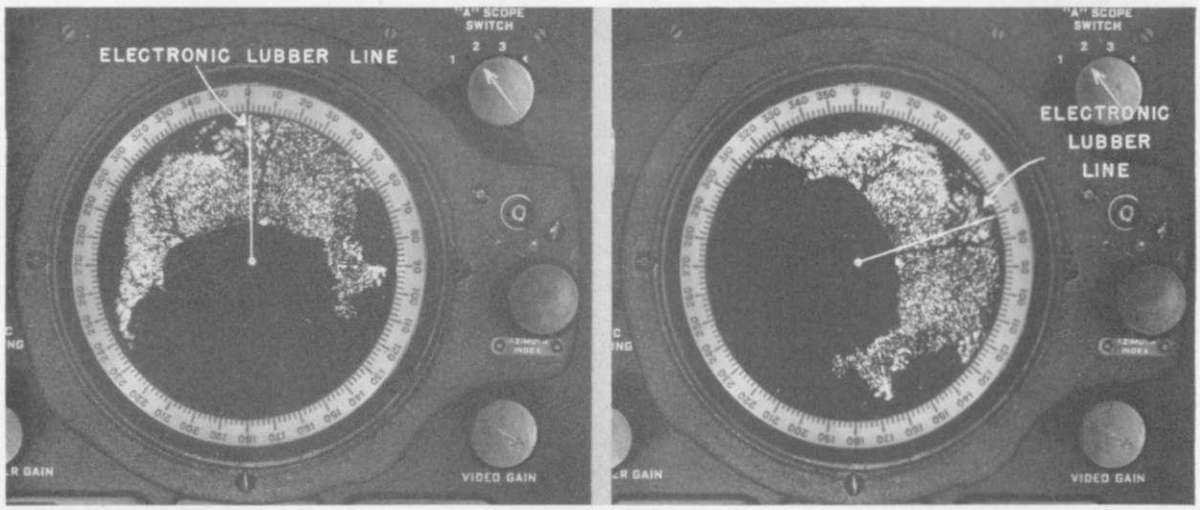


Figure 2–38.—APS–15 incorporates in its design the feature of automatic azimuth stabilization. Above, left, is shown the scope presentation with automatic azimuth stabilization switched off. Here zero degrees indicates the heading of the aircraft and all targets appear relative to the aircraft's heading. At the right the same pattern is shown when automatic azimuth stabilization is turned on. The land pattern has shifted to its true geographic location with respect to the top (zero degrees) of the scope, which is north. The electronics lubber line indicates this heading of the aircraft.

separate these targets, an "Open Center" control has been provided. Operation of this control makes it possible to move the start of the trace outward from the center of the screen which, in effect, very noticeably expands the presentation of these scope images originating from targets close in.

2. *Antenna tilt.*—By manual control of a motor-driven mechanism the antenna assembly can be tilted from 20° above to 20° below the horizontal axis of the aircraft. Control of antenna tilt enables the operator to vary the angle at which the antenna beam travels outward around the aircraft. Angles of tilt are indicated on a tilt meter located on the panel of the receiver-indicator unit.

Tilt affects range. With low angles of tilt, the area traversed by the beam is small; with high angles of tilt, the area traversed can be extended to the limits of the horizon.

With a fixed tilt setting it is possible that changes in the flight attitude of the aircraft will cause the transmitted antenna beam to shift from a target area during successive sweeps of the antenna. To counteract this effect, automatic tilt stabilization may be employed.

3. *Automatic tilt stabilization.*—Automatic tilt stabilization employs a gyro system connected to the tilt mechanism in such a way that when the antenna is manually adjusted to any preset angle by the tilt switch, this angle of tilt will be maintained regardless of limited (20°) changes in the aircraft attitude of flight, within a range of 20° above or below the horizontal axis of the plane.

4. *Automatic azimuth stabilization.*—When the automatic azimuth stabilization feature of AN/APS–15 is used, information from the aircraft's flux-gate compass is related to the motor-driven mechanism of the antenna spinner so as to cause the indicator sweep rotation to be oriented with respect to true north. As a result, target patterns are displayed on the scope screen oriented with respect to true north, and they remain so oriented regardless of changes in the heading of the aircraft. See figure 2–38.

5. *Manual sector scan.*—By means of switches mounted on the control unit, the normal 360° rotation of the antenna spinner can be interrupted to provide manual control of antenna movement. Operation of the "L–R" switch causes the antenna to rotate left or right, at will. This is particularly helpful when a target indication in a specific sector is to be inspected more closely and more quickly than is possible with the 360° rotation. See figure 2–39.

6. *Automatic sector scan.*—Sector scanning a specific area can be accomplished automatically. Suitable controls on the control unit permit any sector of the full 360° to be selected, while other controls regulate the width of the sector scan. Both automatic sector scan and automatic azimuth stabilization can be employed simultaneously to display the scanned sector on the scope in its true relationship to north.

7. *Electronic lubber line.*—Employment of this feature produces intermittently a line of light on the scope whose azimuth position indicates the heading of the aircraft. A microswitch aligned with the fore-aft axis of the aircraft controls electronic circuits in the equipment which produce a line of light on the scope screen each time the spinner sweeps past the dead-ahead position. See figure 2–40.

8. *Altitude determination.*—Two features of design assist the AN/APS–15 operator to determine the absolute altitude of his aircraft between the limits of 10,000 to 36,000 feet, with an accuracy of ±100 yards. They are the A-scope on the receiver-indicator and the altitude con-

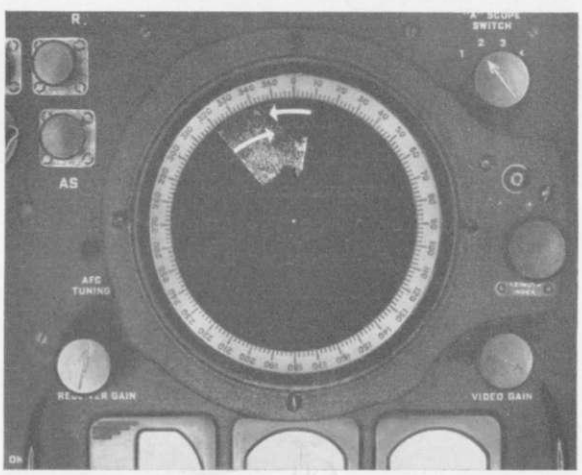


Figure 2–39.—Where a specific area is to be searched the APS–15 can be set to sector scanning (either manual or automatic) causing the antenna to scan the transmitted beam back and forth over the desired area. On the scope only the area being scanned appears as a radar image.

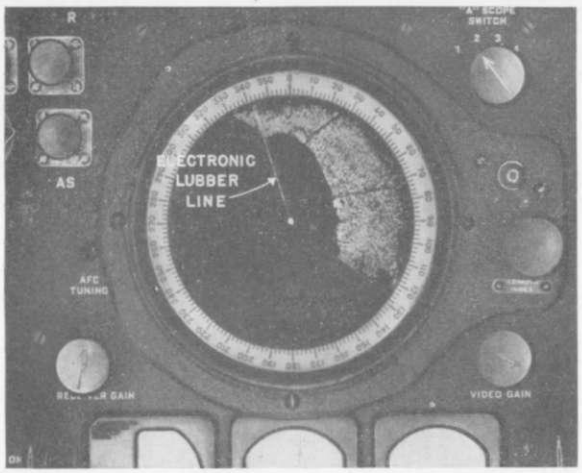


Figure 2–40.—The use of the electronic lubber line on the APS–15 provides a quick and accurate indication of the aircraft's heading. When automatic azimuth stabilization is used the heading indicated by the electronic lubber line is true as shown above. When automatic azimuth stabilization is not used the electronic lubber line when switched on will appear at zero degrees.

trol on the computer unit. When the range unit is switched on, a downward projecting pip, called the altitude pip, is developed near the left end of the A-scope's horizontal trace. Rotating the altitude control on the computer unit shifts the position of the sea return on the A-scope trace. When the sea return is moved so that its left edge is in coincidence with the altitude pip, the absolute altitude of the aircraft is indicated by the position of a sliding index hairline along a vertical scale on the computer box. (With the AN/APS–15A or AN/APS–15B, the minimum altitude that can be determined accurately is 3,000 feet.)

9. *Drift determination.*—An estimation of drift is possible when the automatic azimuth stabilization and electronic lubber line features are used. The scribed movable azimuth index line located over the face of the PPI is rotated so as to align it parallel to the movement of the pattern on the scope screen. The angle this line makes with the electronic lubber line is an indication of the aircraft's angle or drift.

10. *Precision ranging.*—Use of the range unit, computer box and control unit produces a range circle on the PPI which can be used to indicate the slant range to targets up to a distance of about 45 miles with an accuracy of ±150 yards. See figure 2–41.

When the factors of absolute altitude, ground speed, drift, and type of bomb are known and the equipment is adjusted accordingly, the time for bomb release is indicated when the selected target moves in along the scribed azimuth index line (set to represent course) to coincide with the slant range circle.

As a reverse function, the slant range circle can be coincided with a target or signal to denote its slant range.

11. *Sweep delay selector.*—Sweep delay is a design feature incorporated in AN/APS–15 which allows the start of the trace on the PPI and PRI to be delayed in 10-mile steps, up to a total of 200 miles. When this feature is used in conjunction with the equipment's normal ranges of 5, 20, or 50 miles, the trace then represents the outer portion of the extended area; e. g., if the sweep delay is set to introduce 150 miles of delay and the equipment is set to the 50-mile range, the trace will represent coverage of the last 50 miles of a 200-mile area.

12. *Beacon homing.*—To enable the AN/APS–15 to trigger X-band radar beacons and receive their signals, the AN/APS–15 must be reset from the search function to beacon

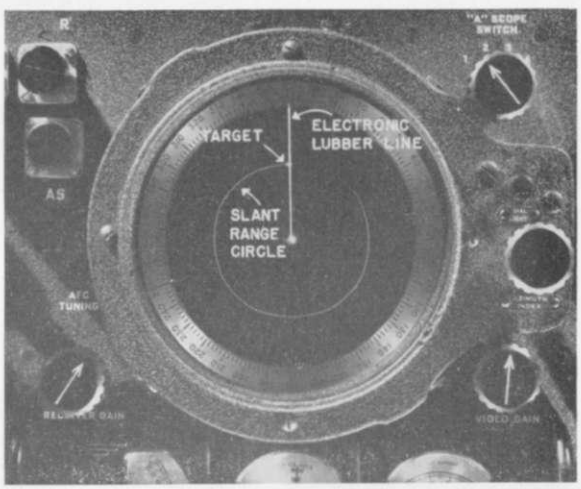


Figure 2–41.—Operation of the ranging feature of APS–15 produces a slant range circle on the PPI scope which can be employed for precision pattern bombing of a selected target. The bomb release point is indicated when the selected target moves down to the slant range circle as produced by setting the equipment for correct altitude, drift, and ground speed.

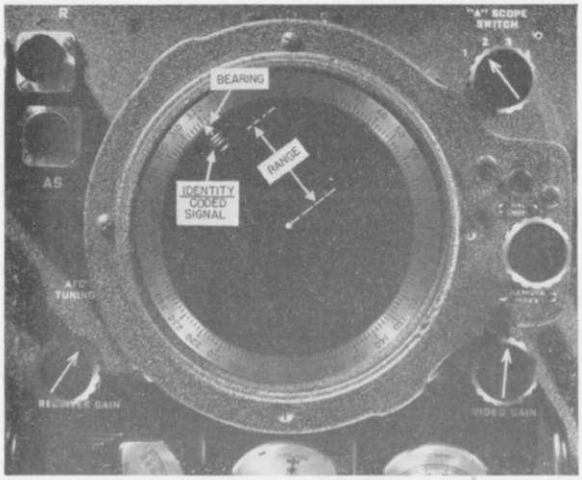


Figure 2–42.—On PPI type scope presentations a beacon signal appears as a series of vertically space dashed lines. Their number and separation denotes the code employed. Range to the beacon is measured from the center of the PPI to the lower edge of the innermost dash.

operation. When so adjusted, the receiver-indicator may be retuned, not to the radar pulse-and-echo frequency, but to the transmission frequency of the X-band radar beacon transmitters, such as AN/CPN–6. As a result, radar echo signals do not appear on the scope screen. The radar beacon signals appear correct in azimuth and range. Identity is indicated by the coding of the beacon signals. See figure 2–42.

The range circles for the 5-, 20-, 50-, and 100-mile ranges can be employed to denote approximate range to a beacon station. By employing the sweep delay feature, beacon signals up to 250 miles away (50-mile range setting plus 200 miles delay) can be detected. The maximum distance that can be displayed on the scope is 250 miles, because the sweep delay selector settings operate only in conjunction with the basic 5-, 20-, and 50-mile range settings on the indicator. It must be remembered that maximum ranges are dependent upon the aircraft's altitude and the line-of-sight distance to the beacon transmitted (see Range, Part III, p. 18).

When more accurate ranging is required, the range unit may be switched on. The slant range circle may then be employed to indicate the exact range to the beacon station. Precision ranging is possible only to 215 miles. Since the maximum radial distance which can be represented by the slant range circle is 15 miles, this figure added to the maximum of 200 miles delay obtainable from the sweep delay selector setting will produce a circle which represents a range of 200 plus 15, or 215 miles.

III. TACTICAL EMPLOYMENT

The tactical employment of AN/APS–15 and the effectiveness with which it contributes to the success of a mission depends in large measure upon the skill of the operator in employing any or all of the features incorporated in its design and in interpreting the scope patterns produced as a result of the use of those features.

A. Search. 1. *Types of targets.*—In search operation, targets may be classified either as single spots or as relatively larger patterns which are produced by land masses.

At long ranges (50-, 100-mile range settings) the size of a target spot on the scope cannot be interpreted to indicate with any degree of accuracy whether the target spot has been produced by one target such as a single ship, or many ships in convoy. It is only after range has been closed that closer inspection of such target spots will reveal the number of targets.

Similarly, the size of the target spot is no definite indication of the actual relative size of

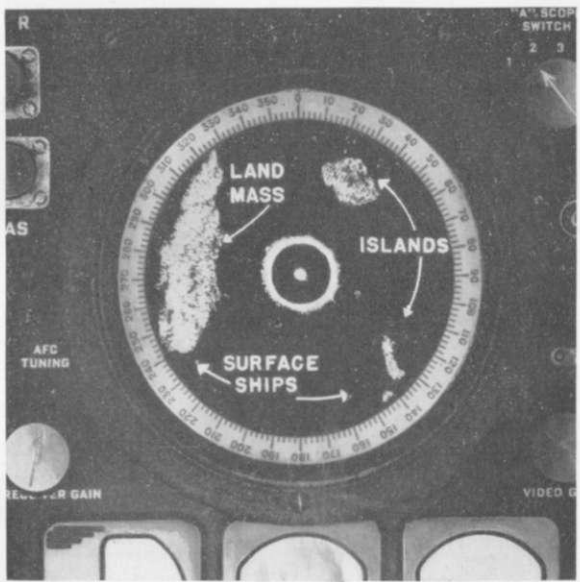


Figure 2–43.—The above view of the APS–15 scope gives an excellent indication of land mass, island, and surface ship targets. The circular pattern around the center of the scope is caused by sea-return reflections.

the target. Large ships bow-on or stern-to may cause target indications on the scope of the same size that smaller ships beam-to will produce.

Images of land masses, coastal areas and islands are faithfully reproduced on the AN/APS–15 scope screen with a degree of fidelity almost approaching that of a relief map. See figure 2–43. Mountainous or rugged terrain areas will stand out more sharply than flat areas. Coast lines are well defined. At long ranges, cities appear as concentrations of light on the scope pattern at a greater intensity than the surrounding areas. Rivers and harbors can be identified. Specific buildings amongst many cannot be identified.

Thunderheads, because of their great moisture content, reflect radar echoes and cause distinctive patterns to appear on the scope screen. These patterns resemble those of land somewhat in that they are fairly solid, but have fuzzy, indistinct edges. The upward tilt of the antenna required to pick up "fronts," plus the fact that reference to charts of the area will determine whether land echoes can be expected, will assist in identifying fronts as such.

Because echoes from weather fronts are as bright as echoes from other types of targets, heavily clouded areas clutter the scope, tending to mask target areas. This and heavy precipitation may mask more distant radar echoes, tending to reduce the effective range of the equipment.

For the study of echoes due to weather, the A-scope of the AN/APS–15 should be used in conjunction with the PPI for the following reasons:

(*a*) The A-scope permits a study of small variations or changes in amplitude of a returned echo which ordinarily would be masked out on the PPI. The A-scope accurately shows the relative signal strength of returning echoes. The relative density of clouds can be determined from this information.

(*b*) Due to the high persistence of the PPI's fluorescent screen, a sudden change is not as apparent on the PPI as on the A-scope.

(*c*) The A-scope measures contours of clouds better than the PPI scope. On the PPI, two or more clouds relatively close together would appear as one large cloud. On the A-scope, however, there would be a noticeable separation between the echoes returning from the two clouds.

2. *Altitude/range.*—The range at which targets may be displayed on the scope depends almost entirely on the aircraft's altitude. At an altitude of 2,000 feet, the line-of-sight distance to the horizon is about 50 miles. At this altitude, even though the 100-mile range is used, surface targets at distances greater than 50 miles will not be seen. (See altitude chart, fig. 2–17.)

Altitude plays an important part not only in determining the area covered by the sweep of the beam but also in producing adequate resolution and definition of a target. Land mass targets observed at low altitudes generally are not as well defined on the scope as the same targets observed at greater altitudes. A limiting factor, however, is the production of a larger sea return as the altitude is increased. Large sea returns tend to mask targets close at hand. From a practical standpoint, some balance must be struck between large sea return at high altitudes as weighed against better resolution of targets at the higher altitudes.

3. *Conversion of slant to horizontal range.*—Any radar equipment deals in slant ranges. From the computer drum can be read the distance which represents the hypotenuse of a right triangle of which the vertical distance from the airplane to the ground is one side and the horizontal distance from a point directly beneath the airplane to the target is the other side. The difference between slant range and ground range is negligible whenever the range is more than five times the altitude, but for targets close by, the difference of slant range versus actual range must be taken into consideration if an accurate range indication is required.

4. *Tilt control and flight attitude.*—Tilt control, tilt stabilization, and automatic azimuth stabilization all contribute to clarity of target definition and to the ability to maintain a target indication on the scope, regardless of limited maneuvers of the aircraft.

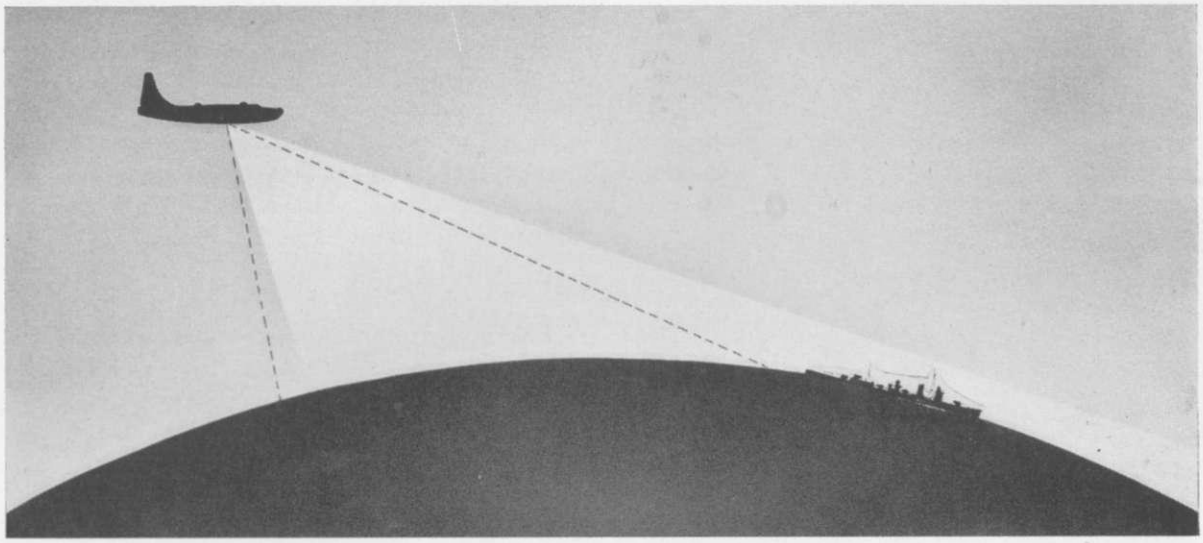


Figure 2–44.—When searching at lower altitude the antenna tilt must be raised in order to increase the radar horizon range.

Tilt is not critical for targets which are already within the beam; but in order to pick up targets which are beyond the beam coverage, the antenna must be tilted upward. Particularly with respect to aircraft targets, the upper edge of the beam must be raised by means of the tilt control in order to include such targets in the beam's coverage. See figure 2–44. The tilt control also functions to insure that with decrease in altitude the beam may be progressively raised to keep the target in the area covered by the beam.

5. *Ranges of detection.*—The actual ranges at which targets may be observed depend upon such factors as:

(*a*) Varying performance of individual equipments.
(*b*) Operator skill.
(*c*) Altitude.
(*d*) Type and composition of target.
(*e*) Intelligent use of tilt control.

The following table of average ranges to be expected for various types of targets is indicative only in a general way of what can be expected in the use of AN/APS–15:

Target	*Naut. miles*
Large coastal cities	95
5,000-ton ship	40
Harbor buoys	15

B. Navigation. 1. *Aids to precision navigation.*—Because of the high-fidelity, maplike scope presentation of prominent land masses which are produced when AN/APS–15 is set for search, and the display of code-identified beacon signals when set for beacon reception, precision navigation is one of the main uses to which AN/APS–15 equipment can be put. A number of design features contribute to precision navigation:

When set for Search

(*a*) The electronic lubber line shows the *heading* of the aircraft. (See figure 2–45.)

(*b*) The scribed azimuth index line, when aligned parallel to target movement across the scope screen, can be used with the electronic lubber line to indicate angle of drift.

(*c*) With the slant-range circle feature, precision ranging on a given target can be conducted over a measured period of time to calculate absolute ground speed.

(*d*) Azimuth stabilization allows viewing of a truly oriented maplike land mass area for comparison with charts of the same area.

(*e*) Knowing the above, a collision course with a selected target can be established.

When set to Beacon

(*f*) Relative bearing of beacon stations can be ascertained by lining up the scribed index line with the center of the coded signal and noting its azimuth position with respect to the

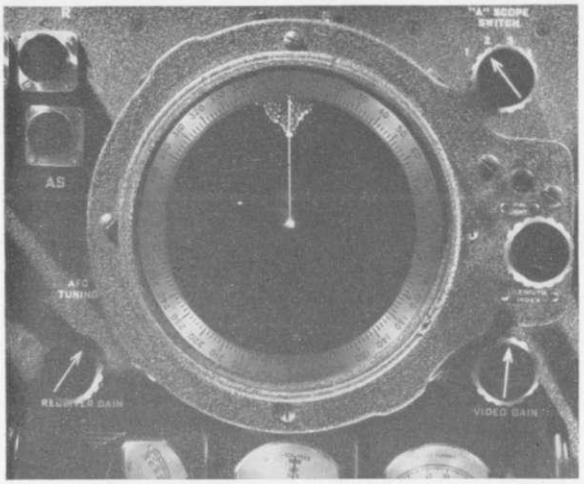


Figure 2–45.—When it is desired to home on a target such as a point of land as indicated in the view above the use of the electronic lubber line will assist in maintaining the heading of the aircraft toward the selected target.

azimuth indicator scale around the periphery of the scope.

(*g*) Use of azimuth stabilization will orient the beacon signals on the scope to their true geographic location.

(*h*) By the use of the sweep delay sector feature, beacon station signals up to a range of 250 miles can be received, provided the aircraft is flying at an adequate altitude. (See line-of-sight chart, figure 2–17.)

(*i*) Precision ranging on beacon station signals permits accurate interpretation of slant range to the beacon up to approximately 215 miles.

2. *Homing: Radar targets.*—All of the factors affecting target resolution and definition, such as altitude, range, antenna tilt, terrain contour, and weather, enter into a consideration of effective homing.

Heading and drift determine the track which must be maintained if it is desired to set a collision course for homing on a specified target. See figure 2–45. When a target in a specific area has been selected for homing purposes, the job can be simplified through the use of the electronic lubber line, azimuth stabilization and sector scanning. Use of the range marker circles will assist in approximating target ranges. Use of the slant range circle (within a range of 45 miles) will denote accurate target range.

3. *Homing: Beacon targets.*—The factors outlined in the preceding paragraph apply to a limited degree in homing on the signal from a radar beacon station. The exception is that with radar beacon signals the reception ranges are greater than for target echo ranges. This is because a radar beacon signal is a directly transmitted powerful signal while the target echo is a weak reflection of the original radar transmission. Also, a radar beacon station, if it is in operation in the area being patrolled and within range, produces a coded signal on the scope screen, to furnish a positive indication of the beacon transmitter's identity, range and bearing. See figure 2–46.

C. Bombing. 1. *Pattern bombing.*—At the altitudes at which AN/APS–15 may be employed for bombing, 10,000 to 36,000 feet, the target areas must necessarily be general in nature. The equipment is suitable for pattern bombing—not for bombing of specific objects.

Through overcast, or under conditions of poor or zero visibility, AN/APS–15 can furnish information on:

(*a*) The aircraft's ground speed.
(*b*) The aircraft's angle of drift.
(*c*) The aircraft's true heading.
(*d*) The track to be flown.
(*e*) The closing range of the target area.

From a knowledge of these factors and the

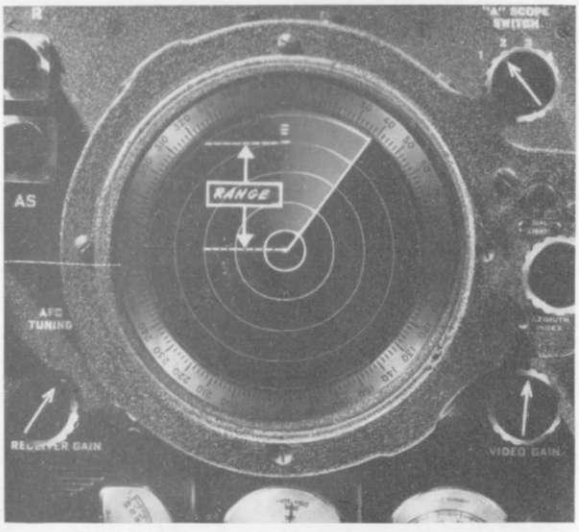


Figure 2–46.—After a beacon signal is picked up the aircraft is turned until the signal appears dead ahead. Range to the beacon may be judged with the aid of the range circle.

type of bomb being used, an operator can determine, through the use of the slant range circle, when the bomb-release point has been reached.

2. *Absolute ground speed and drift angle.*—Although AN/APS–15 can be employed to determine absolute ground speed and drift angle, it should not be relied upon solely to furnish this information when other means are available. Rather, AN/APS–15 ground speed and drift information should be used to supplement and cross-check the data provided by other proven means.

3. *Low-altitude bombing.*—Although the equipment is designed for bombing from altitudes above 10,000 feet, it can be used for low-altitude bombing when fitted with a low-altitude antenna reflector which is supplied with the equipments. However, because it is difficult to follow the target on the PPI at ranges of less than 1 mile, AN/APS–15 is suited to low-altitude bombing only when the proper release point can be determined visually.

NOTE.—A new series of air-borne search radars, designated as AN/APS–30 Series, is under development to replace generally AN/APS–3 and the AN/APS–15 series. The AN/APS–30 series consists of two basic equipment and two alteration kits, as follows:

AN/APS–31 is an X-band search radar containing many of the special features of design and operation contained in AN/APS–15. Its antenna scans through a forward-looking field of view producing a scope presentation of a 160° V on a PPI-type scope.

AN/APS–32 consists of a kit of antenna and other essential replacements which when used with the AN/APS–31 changes it from X-band operation to K-band operation.

AN/APS–33 is an X-band search radar similar to AN/APS–15 and AN/APS–31, but furnishing either a full 360° PPI-type presentation or a 60° V-type presentation, the apex of the latter appearing above bottom center of the scope face.

AN/APS–34 is a change over kit for use with AN/APS–33 to change it from X-band operation to K-band operation.

AN/APS–15A AND AN/APS–15B

NOTE.—The function, uses, description and tactical employment of AN/APS–15A and AN/APS–15B are, in general, the same as those described for AN/APS–15. Therefore, only the changes and improvements incorporated in the AN/APS–15A and AN/APS–15B are described herein.

A. SPECIAL FEATURES OF AN/APS–15A and AN/APS–15B

1. *Veeder counter.*—The computer unit of the AN/APS–15A and AN/APS–15B models use a Veeder counter in place of the computer drum used in the AN/APS–15, for reading absolute altitude and slant range. The Veeder counter is more accurate, does not have the errors of the computer drum and is easier to read. The counter is calibrated from 3,000 feet up to 90,000 feet (approximately 15 miles).

2. *Ranges and range markers.*—The AN/APS–15A and AN/APS–15B models provide two fixed operating ranges—zero to 50 and zero to 100 miles. A third range is continuously variable between the limits of 5 and 30 miles. To assist in judging approximate ranges to a target, a range selector switch enables the operator to select any one of three sets of range circles for any one of the three operating ranges. The circle separation is as shown in the following table:

Number of range marks	*Interval between range marks*
100-MILE RANGE	
10	10
20	5
100	1
50-MILE RANGE	
5	10
10	5
50	1
5- TO 30-MILE RANGE	
1 to 3	10
1 to 6	5
1 to 30	1

3. *Sweep timing.*—In the AN/APS–15, the open center control was employed where it was necessary to expand the display of targets crowded close to the center of the PPI screen. In the AN/APS–15A and AN/APS–15B, the sweep timing control, in addition to being used as a means for expanding the pattern (see Open Center Control, p. 42), also operates to contract the screen pattern. Operation of the sweep timing control makes possible the elimination of

the blank area in the center of the PPI which occurs when flying at the higher altitudes, thus allowing the entire scope face to be utilized for viewing targets. Also, in those cases where a portion of a target image appears at the extreme outer edge of the scope screen, manipulation of the sweep timing control shrinks the scope pattern, bringing the target echo within the boundaries of the scope screen.

4. *Precision ranging.*—With AN/APS–15A and AN/APS–15B, precision ranging on objects up to approximately 100 miles is possible. When the bomb release marker is adjusted to coincide with the target image on the PPI screen, the distance to the target is that shown on the computer counter (in feet) plus the delay set in by the sweep delay selector (in nautical miles). For targets within a range of 15 miles (maximum limit of the range circle), it is not necessary to employ sweep delay.

5. *Bomb release point data.*—In pattern bombing, 12 separate counter dials are supplied with the computer unit, any one of which may be selected for insertion in the unit, depending upon the type of bomb employed, and different indicated air speeds.

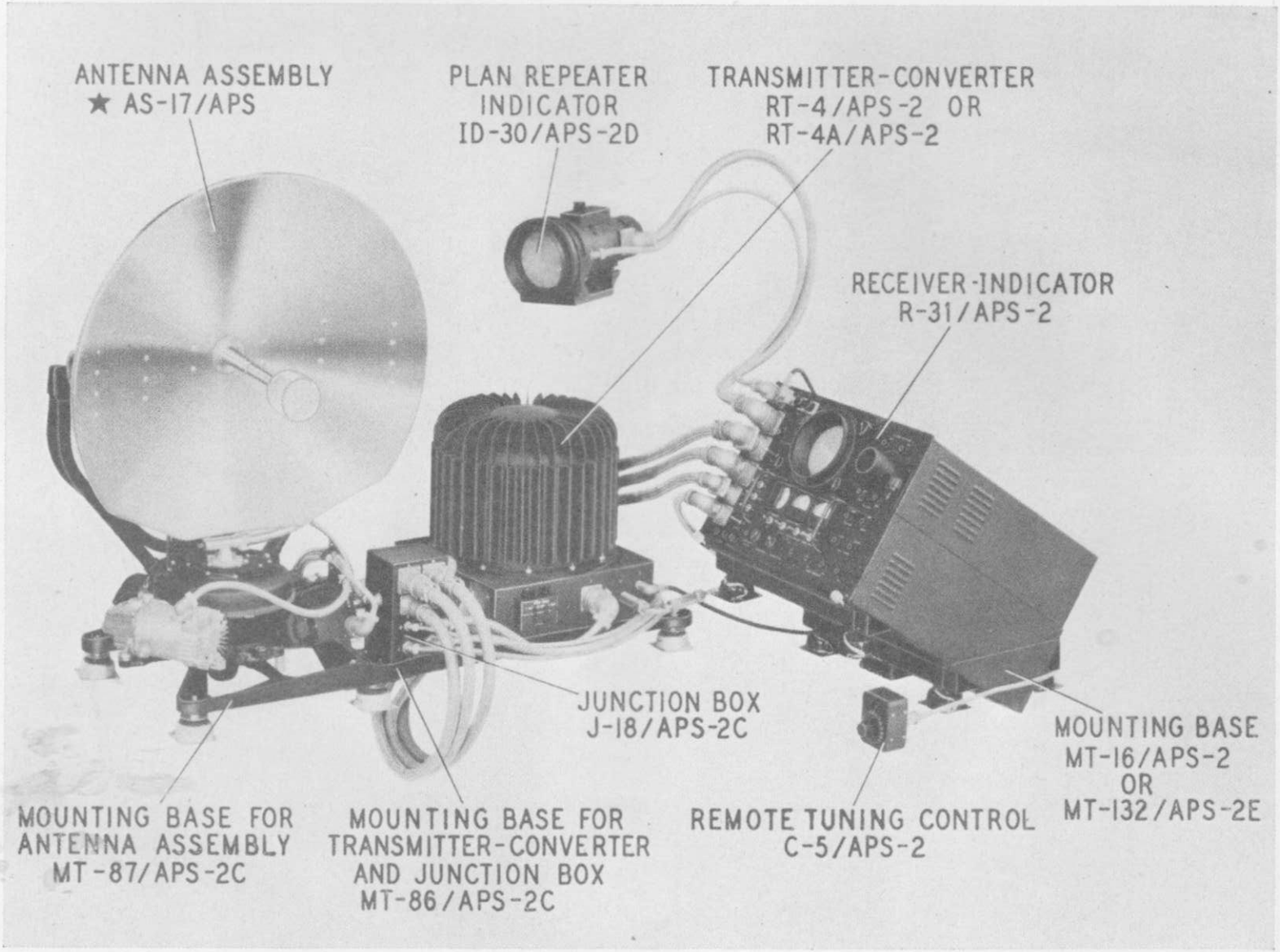

ANTENNA ASSEMBLY
★ AS-17/APS
PLAN REPEATER
INDICATOR
ID-30/APS-2D
TRANSMITTER-CONVERTER
RT-4/APS-2 OR
RT-4A/APS-2
RECEIVER-INDICATOR
R-31/APS-2
JUNCTION BOX
J-18/APS-2C
MOUNTING BASE
MT-16/APS-2
OR
MT-132/APS-2E
MOUNTING BASE FOR
ANTENNA ASSEMBLY
MT-87/APS-2C
MOUNTING BASE FOR
TRANSMITTER-CONVERTER
AND JUNCTION BOX
MT-86/APS-2C
REMOTE TUNING CONTROL
C-5/APS-2

Fig. 2–47A

Fig. 2–47B

Figure 2–47.—The AN/APS–2 (or George) series of PPI type radars display scope presentation similar to the APS–15 but not with as high a degree of target resolution A, above shows a convoy while B shows the same convoy at a lower range setting. C and D are characteristic land mass presentations.

ASG—AN/APS–2 SERIES

NOTE.—The ASG—AN/APS–2 series of air-borne radars—ASG, ASG–1, AN/ASP–2 (ASG–3), AN/APS–2A (ASG–2), AN/APS–2B (ASG–2), AN/APS–2C (ASG–3), AN/APS–2D, AN/APS–2E—are somewhat similar in design and identical in function, the design differences arising chiefly from changes in mounting dimensions and mounting methods to adapt the equipment to the type of aircraft in which installation is being made. The AN/APS–2D and AN/APS–2E, in addition, substitute an "open center control" in place of the PRI focus control on the receiver-indicator, the latter control being removed to the PRI itself. The models in this series are the forerunners of the AN/APS–2F and AN/APS–15 radar equipments. The section on AN/APS–2F which follows is applicable in general to all of the ASG—AN/APS–2 models. Those items marked with an asterisk (*) represent features incorporated in the AN/APS–2F which are not contained in the earlier equipments.

I. FUNCTION

A. PRIMARY PURPOSE. AN/APS–2F is an S-band radar designed primarily for general airborne search operations in heavy patrol aircraft.

B. SECONDARY USES. AN/APS–2F may be employed for navigation, beacon homing, and, when used in conjunction with other electronic equipment, it may be employed for target identification.

II. DESCRIPTION

A. MAIN COMPONENTS. The main units of AN/APS–2F are:

1. Transmitter-converter unit.
2. Rotating antenna-spinner assembly.
3. Receiver-indicator, housing the operator's viewing (PPI) and monitoring (A) scopes.
4. Repeater (PRI) scope, for pilot or navigator use.
5. Control unit.

B. ANTENNA SCAN AND SCOPE PRESENTATION. In general, the operating characteristics of AN/APS–2F and its antenna scan and scope presentation are identical with AN/APS–15 (see p. 39), with the following exceptions:

1. AN/APS–2F operates in the S-band of frequencies.
2. Its antenna beam is a 9° cone.
3. Its operating ranges are identical with AN/APS–15 (5, 20, 50, 100 miles).

C. SPECIAL FEATURES. AN/APS–2F incorporates in its design certain special features

CONFIDENTIAL

Fig. 2–47C

Fig. 2–47D

which enhance its value for search and navigation use. They are:

1. Antenna tilt.
2. Automatic tilt stabilization.*
3. Automatic azimuth stabilization.*
4. Manual sector scan.
5. Automatic sector scan.*
6. Automatic frequency control.*
7. Electronic lubber line.*
8. Beacon operation.
9. Open center control.

III. TACTICAL EMPLOYMENT

A. Search. 1. *Types of targets.*—Target definition and resolution are not as good as that obtained by the AN/APS–15 (see p. 39), due to the relatively lower operating frequency (S-band) employed by the AN/APS–2F, and to the 9° beam as compared to the 3° beam width of the AN/APS–15.

2. *Tilt.*—The AN/APS–2F antenna produces a 9° conical beam which must be controlled by the tilt switch to keep it on a target. Because of the limited coverage obtained by the beam, antenna tilt is critical. The ability to keep targets in the beam is dependent upon altitude and the intelligent use of the tilt control, particularly as the range to the target is closed. Also the 9° conical beam (as compared to the beam spread in the vertical plane produced by the special antenna design of the AN/APS–15) results in limited coverage, in depth, of land masses as displayed on the scope. This, too, is a function of altitude and correct antenna tilt.

3. *Range settings.*—Operating ranges are the same as for AN/APS–15 (5, 20, 50, 100 miles).

B. Navigation. 1. *Homing.*—Homing on targets and beacons is the same as for the AN/APS–15. Precision ranging (as in the case of AN/APS–15) is not possible since a range unit is not included in the AN/APS–2F equipment. Full reliance must be placed on the use of the range marker circles for judging target and beacon signal ranges.

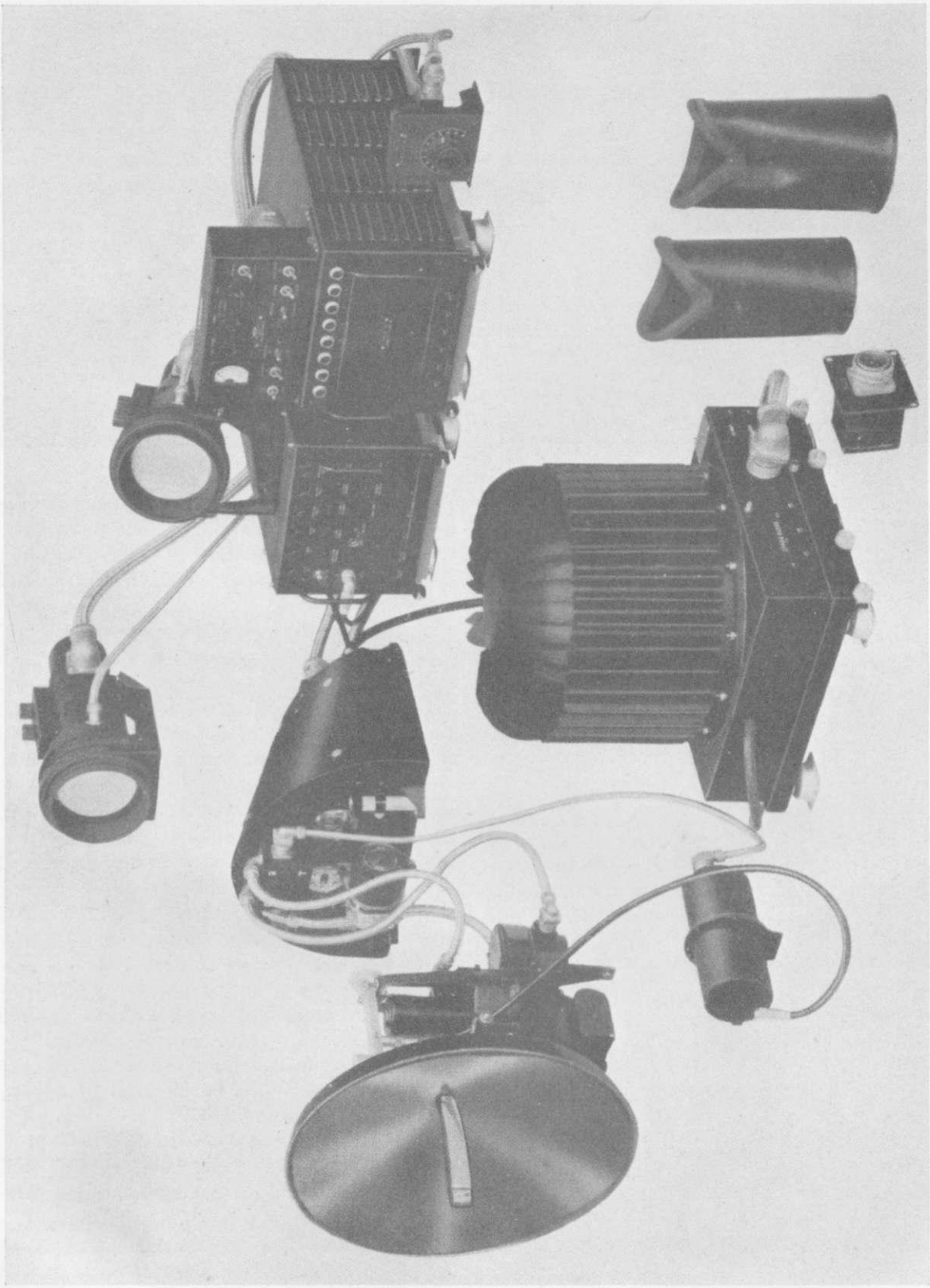
When set for Beacon, the AN/APS–2F operates in conjunction with the AN/CPN–3 (YK) radar beacons. Range coding, as displayed on the PPI, denotes identity, and the position of the indication on the scope screen gives the range and bearing of the radar beacon.

Dependent upon altitude, radar beacon signals are receivable up to the maximum range (100 miles) of the equipment.

C. Bombing. Bombing with AN/APS–2F is essentially a matter of employing any or all of the special features of this equipment in order to home on a target to within visual contact.

(For low-altitude precision bombing with AN/APS–2F see AN/APQ–5B. Part II, p. 83).

*Features incorporated in AN/APS–2F not found in earlier ASG–AN/APS–2 series equipments.



AN/APS-3

AN/APS–3

NOTE.—The AN/APS–3 is a later model of the ASD, ASD–1 series.

I. FUNCTION

A. PRIMARY PURPOSE. AN/APS–3 is an X-band air-borne radar employed primarily for search in medium patrol aircraft.

B. SECONDARY USES. This equipment can be used for radar navigation, homing on radar beacons (AN/CPN–6) and for radar bombing. When employed in conjunction with other suitable identification equipment it can be used to display IFF signals. (See Part IV, page 113.)

II. DESCRIPTION

A. MAIN COMPONENTS. AN/APS–3 consists of the following major units:

1. Antenna unit.
2. Transmitter-converter (r–f head).
3. Modulator unit.
4. Receiver amplifier.
5. Rectifier unit.
6. Control unit.
7. Azimuth calibrator.
8. Repeater indicator.
9. Connector cables, viewing hoods, and dummy indicator.

R–F head.—The inclusion of the radio-frequency head in the AN/APS–3 design overcomes one of the main drawbacks to efficient operation so pronounced in the earlier ASD version of the equipment.

In the ASD (for purposes of comparison) the generated pulses were fed from the modulator to the antenna through a long, complicated wave guide which both from a mechanical and electrical standpoint was inefficient. As a result, the effective power was attenuated before reaching the antenna.

In the AN/APS–3, part of the transmitter and receiver circuits are moved up to the r-f head, which is located close to the antenna. The transmitted pulses pass through a short wave guide direct to the antenna with no appreciable attenuation. Received echoes likewise pass through the short wave guide to the preamplifier located in the r-f head, where they are demodulated before being passed to the remainder of the equipment through flexible coaxial cables; thus, the long, inefficient wave guide is eliminated.

B. ANTENNA SCAN AND SCOPE PRESENTATION. 1. *Beam coverage.*—The antenna unit consists of a parabolic reflector and antenna feed assembly connected to a motor-driven gear box so that the antenna and parabola are mechanically and electrically caused to sweep an arc of 160° ahead of the aircraft at a repetition rate of about 35 cycles per minute. The parabola nods over an arc of 2° from the horizontal during the sweep.

The antenna-parabola assembly projects the r-f pulses in a conical beam of approximately 5°.

As the antenna sweeps the r-f beam through its 160° of arc (80° either side of center), a nodding action is imparted to the parabola at the completion of each sweep, resulting in a nod downward of 2°, a sweep of 160°, a nod upward of 2°, the return sweep, etc. Although the azimuth sweep angle is 160°, only 150° of this angle is calibrated, as 5° are used at each end of the sweep for the nodding action.

2. *Type of scan.*—Two scopes are provided; one is the main scope for the operator's use, the other, the auxiliary scope for pilot or navigator use. Both scopes are of the B-scan type. (When either scope is removed from the installation, it must be replaced by the dummy

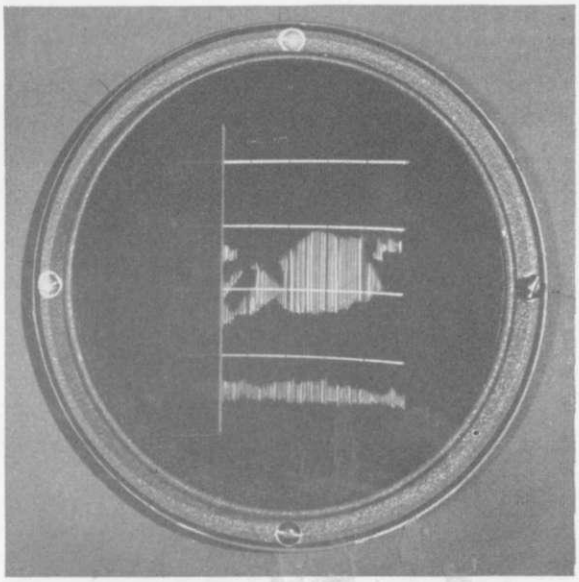


Figure 2–48.—In APS–3 the side-to-side motion of the trace produces a rectangular scope display on the circular scope face.

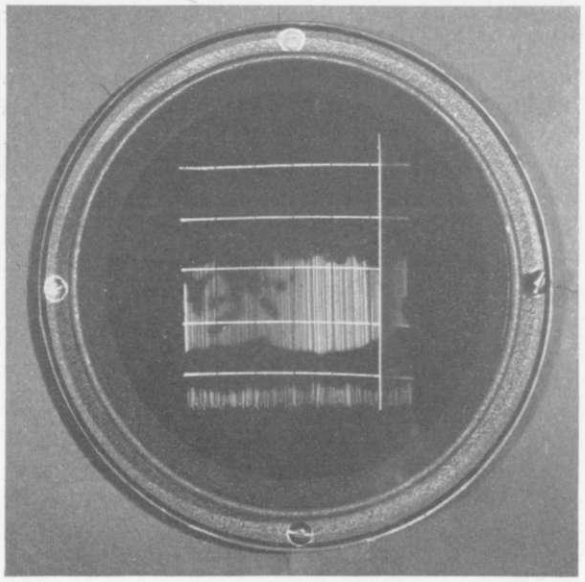


Figure 2–49.—Variations in the brilliance of the laterally moving trace activates the fluorescent coating of the cathode-ray tube indicator producing the target patterns. Above is shown a typical landmass pattern as it appears when the equipment is set to the 10-mile range.

indicator so as not to disturb circuit characteristics.)

The effective 150° of lateral scan of the antenna assembly is translated on the scope into a lateral motion of a vertical trace which moves from side to side in step with the antenna motion, to cover a rectangular area on the scope face. See figue 2–48. The conversion of an angular antenna scan into a rectangular scope display introduces certain disadvantages due to distortion effects (see B-scan distortion, figs. 2–9, 2–10, 2–11, and 2–12), but the advantages of spreading the display of targets close in far outweighs the inherent distortion disadvantages.

Reception of target echoes causes the moving trace to brighten momentarily in its lateral sweep. The bright spots on the trace appear on the scope screen at a range and azimuth corresponding to the target's range and bearing from the searching aircraft. Because of the persistence of the fluorescent coating of the scope screen, target echoes displayed on the scope remain visible for a short period of time after the trace has swept by. Each succeeding trace sweep renews the target echo brilliance. Single ship or aircraft targets are displayed as small spots of light. Land masses, islands, coast lines, etc., show up as relatively large patches of light. See figure 2–49.

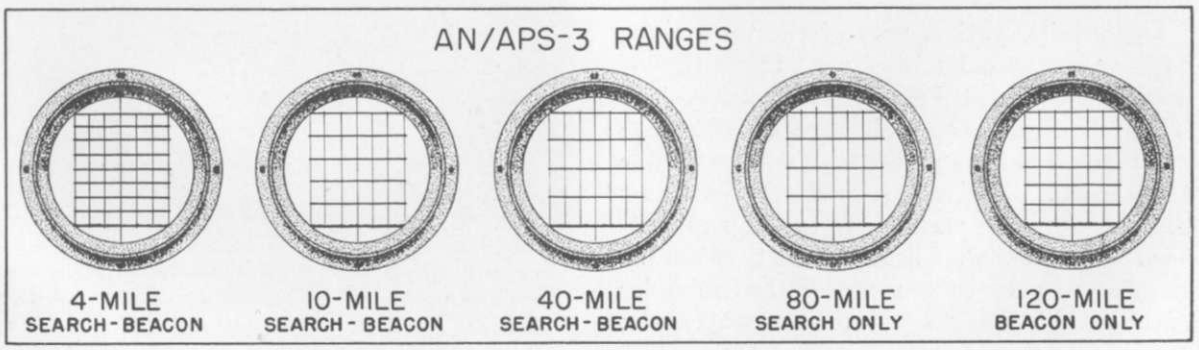
3. *Range settings.*—At the control unit, when the beacon-search switch is set for search operation, the equipment can be used on four ranges of 4, 10, 40, and 80 nautical miles. When set for beacon operation, the ranges are 4, 10, 40, and 120 nautical miles.

As the trace moves from side to side on the rectangular screen, bright spots appearing at graduated intervals along the trace leave a trail behind them to form range markers. These range markers assist in judging the approximate range of target echoes. See figure 2–50.

Range (miles)	*Number of range markers*	*Range mark intervals (miles)*
4	8	½
10	5	2
40	4	10
80	4	20
120*	6	20

*Beacon only.

Figure 2–50.—The horizontal lines on the scope patterns shown here are brilliant lines of light which enable the operator to judge target range.



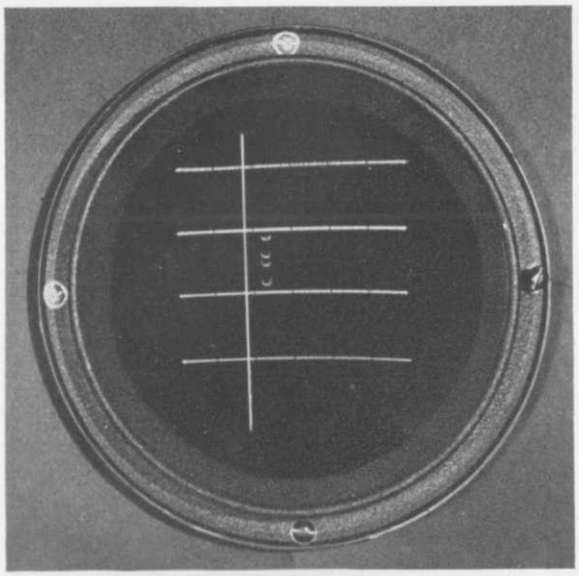


Figure 2–51.—A typical beacon signal appearing on the 40-mile range of the APS–3.

4. *Bearing.*—To indicate bearing, the rectangular screen is covered with a plastic scale containing seven scribed vertical lines. These lines divide the 150° screen into three 25° sections either side of zero degrees at the vertical center. The zero-degree line represents the aircraft's heading.

C. Special features. A number of special design features contribute to the flexibility of use of AN/APS–3. With the exception of one—the azimuth calibrator—all these special features are controlled from the panel of the control unit. They are:

1. Antenna tilt.
2. Beacon reception.
3. Expanded sweep (with electronic lubber line and azimuth calibrator).
4. Phantom target.

1. *Antenna tilt.*—By means of a toggle switch control located on the control unit panel, the beam from the antenna can be tilted through a vertical range 8° above and 8° below the longitudinal axis of the aircraft. Degree of tilt is indicated on the control unit tilt meter. Tilt control enables the beam, with its 2° nod, to cover an area 24° in the vertical plane.

2. *Beacon reception.*—Controls are provided (beacon-search switch and manual tuning) which permit the equipment to be retuned to the X-band radar beacons for reception of radar beacon signals. When the equipment is switched from search to beacon operation, the manual tuning control must be employed to retune the receiver away from the radar's pulse-and-echo frequency to the frequency of the radar beacon (AN/CPN–6). When this is done, radar target echoes do not appear on the scope screen. Only radar beacon signals from beacon stations within range are displayed. See figure 2–51.

3. *Expanded sweep.*—When the expanded sweep is employed, the scope presentation appears over the entire circular area of the scope screen instead of in the form of a rectangle. This operation "magnifies" or expands the center area of the scope so that only the central 60° portion of the rectangular pattern is displayed.

With the "expand" feature being used, an electronic lubber line flashes on the screen each time the antenna scanner passes the dead-ahead position. See figure 2–52.

An azimuth calibrator control can be employed to shift the position of the electronic lubber line. When the electronic lubber line is aligned with a target echo, the dial of the azimuth calibrator will indicate the bearing of the

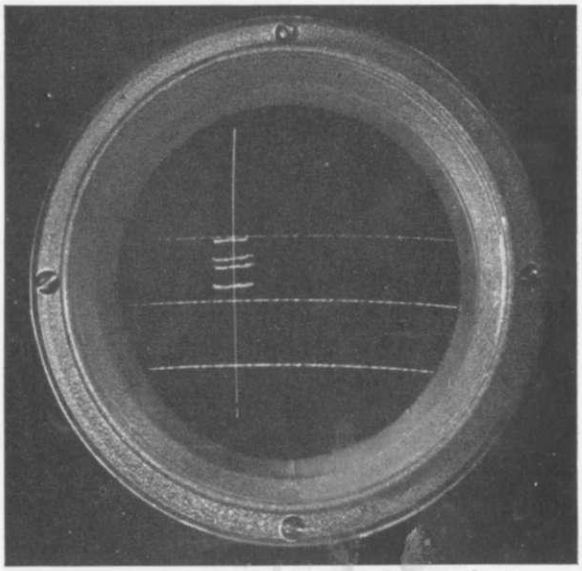


Figure 2–52.—Here the range-coded radar beacon signals appear on the expanded sweep scope display. Positioning of the electronic lubber line allows the relative bearing of the beacon to be accurately determined.

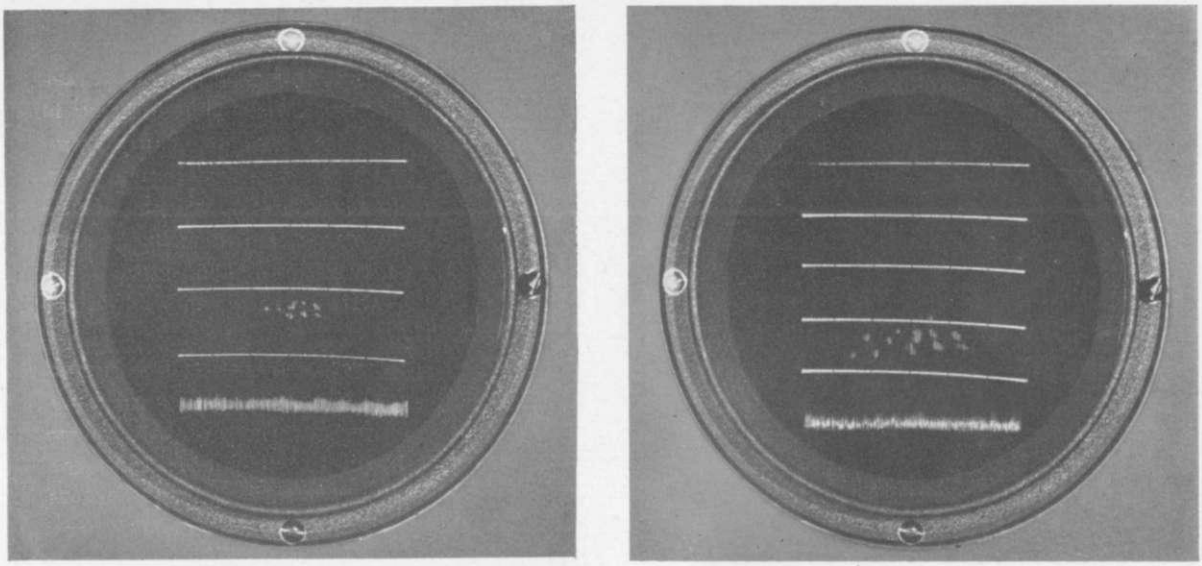


Figure 2–53.—At the left a convoy is shown at about 16 miles on the 40-mile range setting of the AN/APS–3. At the right, the same convoy is shown when the range has closed to the 10-mile range is used.

target with respect to the heading of the aircraft.

III. TACTICAL EMPLOYMENT

A. Search. When employing AN/APS–3, the prime consideration to be borne in mind is that the narrow 5° beam, like a searchlight, "illuminates" only those targets that fall within the path of the beam.

Whether or not the radar beam will strike a target depends upon:

1. The altitude of the search aircraft.
2. The range of the target.
3. The antenna tilt.

1. *Types of targets.*—Depending upon the character of the radar echo spots, the screen display can be interpreted to indicate land masses, islands, coast line, harbors, rivers, airports, and surface ships. Land is indicated on the screen as a relatively large bright patch of light. Coast lines and harbors appear distinctly outlined, but, because of the distortion effect inherent in the B-scan, the scope display of such targets is not a true replica of the actual coastal outline. Rivers and lakes show up as dark areas within the bright land mass patches.

Ships in convoy, at long ranges, produce target spots which appear on the scope as one large spot or as a group of indistinct spots closely bunched together. As the range is closed, however, and the shorter ranges of the equipment used, the group tends to break up into separate, distinct target spots. See figure 2–53.

At extremely close ranges, a single ship target echo will appear on the screen as a long, horizontal line of light, ragged in appearance.

2. *Altitude/range.*—With the aircraft in level flight, the antenna of AN/APS–3 points to the horizon when the tilt meter indicates zero tilt. Depending upon the altitude, then, intermediate distances to the horizon can be covered only when the antenna is tilted downward, or when the altitude is reduced.

3. *Tilt control.*—Because of the comparative narrowness of the beam (5°), tilt control of the AN/APS–3 is critical. As a general rule, operation of AN/APS–3 requires that tilt control be employed almost continuously in order to insure adequate coverage of the area being searched. This is particularly true as the range settings are altered. For instance, for any given altitude, low angles of title will be required to search the area immediately ahead of the aircraft when the 4-mile range setting is employed; but if the equipment is set to any one

of the higher range settings, the tilt must be moved upward in order that the radar beam may encompass the more distant areas.

Target definition can be improved in many cases if, after the target appears on the screen, the tilt control is employed to "aim" the beam directly on the target area. Then, as the range is closed, successive adjustments of downward tilt are necessary in order to keep the target in the beam.

B. Navigation. Because the AN/APS–3 scope screen presentation is maplike in character, radar navigation is relatively simple of accomplishment. Again, the only disturbing factor present is the distortion inherent in the rectangular presentation of a fan-shaped area.

1. *Drift determination and homing on targets.*—When either a radar target or beacon signal is homed on, drift will be apparent if the signal shifts from the central lubber line. The degree of drift can be determined by adjusting the flashing lubber line to bisect the target echo. Degree of drift is read from the dial of the azimuth calibrator.

To home on a selected target, the aircraft is maneuvered until the target appears on the centrally scribed (0°) lubber line. After a period of time, the aircraft's drift will be indicated by the movement of the target away from the zero-degree lubber line, and the course is corrected to compensate for the drift. This course correction will put the target echo on the opposite side of the lubber line from that at which it was observed at the time of drift determination. With the new heading maintained, the electronic lubber line can be set to bisect the new target position. As the aircraft is homed on the target, the echo will move down the electronic lubber line (parallel to the zero-degree line) as the range is closed.

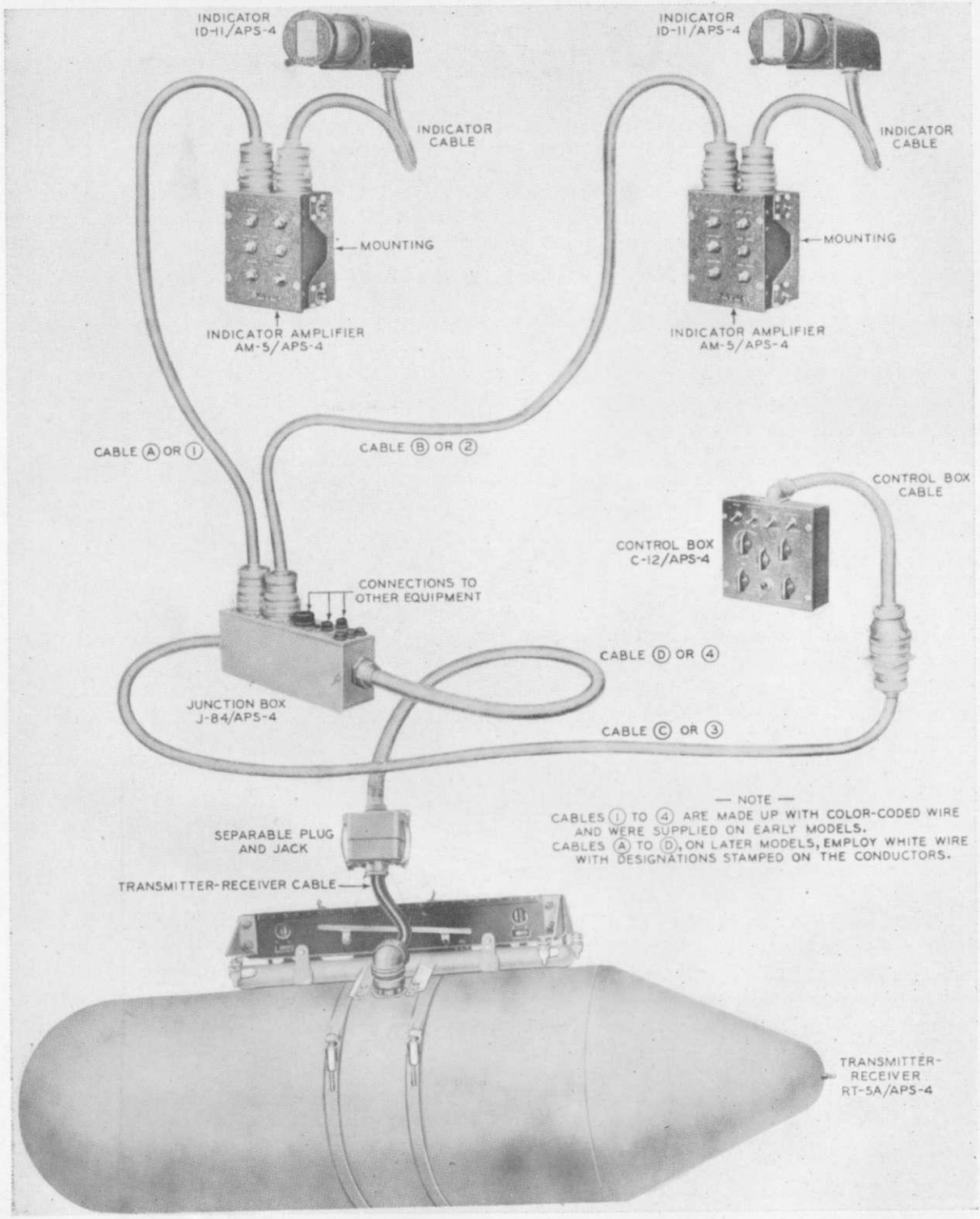
Homing on one of many closely positioned targets is simplified by the use of the "expand" function of AN/APS–3. When this function is employed, the central 60° of the full 150° sweep is displayed over the entire circular area of the scope screen and, in effect, spreads apart or magnifies the target display.

2. *Homing: Beacon.*—When set for beacon operation, AN/APS–3 will display radar beacon signals from beacons located as far away as 120 miles. To receive radar beacon signals, however, the AN/APS–3 must be retuned to the beacon frequency and the aircraft pointed in the general direction of the known beacon stations. Also, to pick up beacon signals at 120 miles the altitude must be such that the beacon station will be within the aircraft's radar horizon.

Received beacon signals appear on the scope screen as a vertical series of short horizontal lines which are range coded. See figure 2–51. At the extreme ranges, the lines will tend to merge together but, as the range is closed, they will separate to show the range coding by which the radar beacon station is identified. Homing on a radar beacon signal is similar to other radar homing techniques.

C. Bombing. Low-altitude bombing of radar targets presupposes the employment of a homing procedure such as that previously described. In this connection, deviations from the collision course must be watched for, particularly within the last mile.

When the expanded scan is used, the echo will broaden considerably and its center is the only reference point of value. Tilt and gain controls must be used constantly to get best target definition. With normal gain, the target will leave a slight "tail," in appearance much like a comet's tail, as it moves down the screen. This can be used in determining a collision course, since the tail must be parallel to the zero line if target bearing remains unchanged.


INDICATOR ID-11/APS-4
INDICATOR CABLE
MOUNTING
INDICATOR AMPLIFIER AM-5/APS-4
INDICATOR ID-11/APS-4
INDICATOR CABLE
MOUNTING
INDICATOR AMPLIFIER AM-5/APS-4
CABLE (A) OR (1)
CABLE (B) OR (2)
CONTROL BOX CABLE
CONTROL BOX C-12/APS-4
CONNECTIONS TO OTHER EQUIPMENT
CABLE (D) OR (4)
JUNCTION BOX J-84/APS-4
CABLE (C) OR (3)
— NOTE —
CABLES (1) TO (4) ARE MADE UP WITH COLOR-CODED WIRE AND WERE SUPPLIED ON EARLY MODELS.
CABLES (A) TO (D), ON LATER MODELS, EMPLOY WHITE WIRE WITH DESIGNATIONS STAMPED ON THE CONDUCTORS.
SEPARABLE PLUG AND JACK
TRANSMITTER-RECEIVER CABLE
TRANSMITTER-RECEIVER RT-5A/APS-4

AN/APS-4

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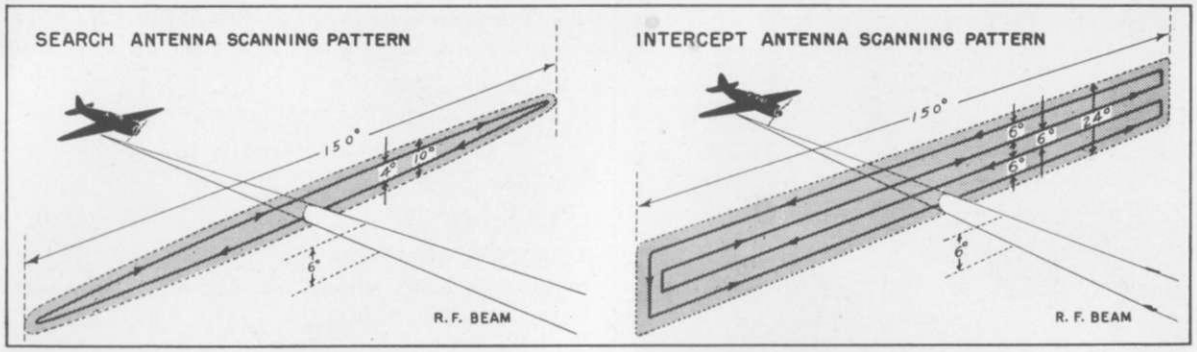


Figure 2–54.—With the APS–4 set for search its antenna executes a two-line scan. When the equipment is set for intercept the scanned area is broadened vertically, the antenna executing a four-line scaninng pattern.

AN/APS–4

I. FUNCTION

A. Primary purpose. AN/APS–4 is an airborne X-band radar employed mainly for search. Its simplified construction allows it to be used in almost any type of aircraft.

B. Secondary uses. AN/APS–4 contains control and design features which permit its use for aircraft interception. In addition, it can be used for radar navigation, radar beacon homing and radar bombing. When used with appropriate IFF equipment, it will furnish display of identification signals.

II. DESCRIPTION

A. Main components. The AN/APS–4 consists of the following pieces of equipment, plus interconnecting cables:

1. Transmitter-receiver.
2. Control box.
3. Indicator (two indicators for multiplace aircraft).
4. Indicator-amplifier (two indicator-amplifiers for multiplace aircraft).
5. Cable junction box.

1. The antenna scanner, transmitter, receiver, and rectifier power supply are mounted in a faired, pressurized bombshell similar to the Mark 17 bomb. This entire unit is supported in a bomb rack for either wing, or under-the-fuselage mounting. In an emergency situation during flight where the security of the radar equipment is endangered by the possibility of its falling into enemy possession, the entire bomblike container may be jettisoned.

2. Only the control unit, indicator scopes, indicator amplifiers, and junction box are mounted within the aircraft.

B. Antenna scan and scope presentation. 1. *Beam coverage.—a.* The antenna beam is a 6° cone and may be tilted by manual control from 10° above, to 30° below the longitudinal axis of the aircraft in which it is installed.

b. On search, the 6° conical antenna beam scans through 150° in azimuth and executes a two-line scan, with a 4° nod, to cause the beam to cover 10° in a vertical plane.

c. On intercept, the beam executes a four-line scan, with 6° between lines, to cover a vertical plane of 24°. See figure 2–54.

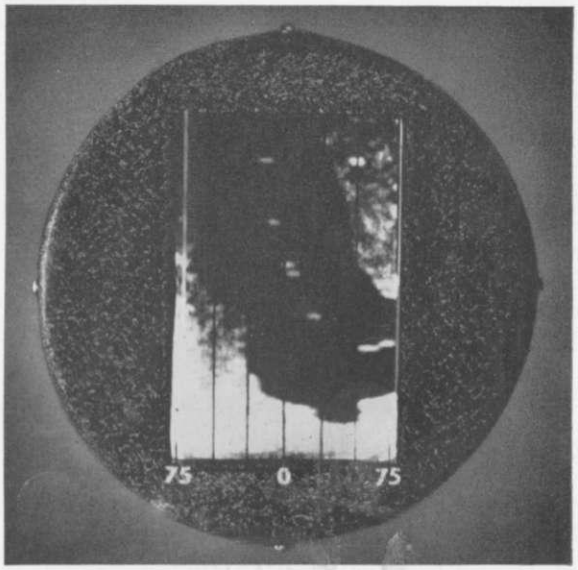


Figure 2–55.—A scope presentation of the APS–4 when set for the 20-mile range. The dark area represents a bay while the light area represents the land on either side. Note the surface ship targets in the convoy proceeding up the bay.

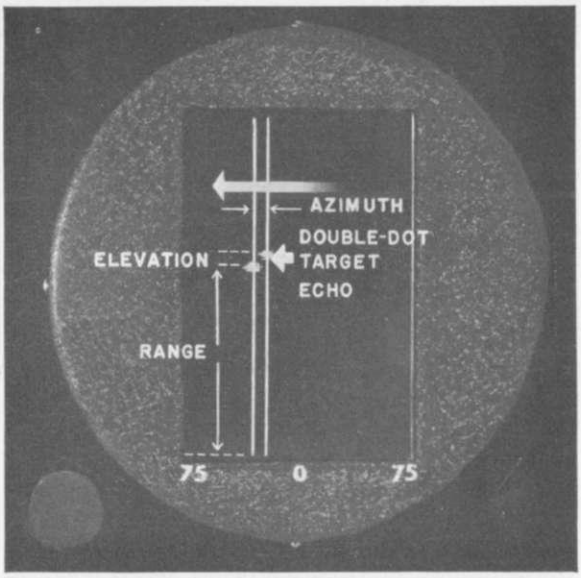


Figure 2–56.—The APS–4, when set for intercept, produces a double, laterally moving trace. An aircraft target is shown as a double dot.

2. *Type of scan.*—*a. B-scan.*—When set for search, the B-type scan presents target images on a rectangular (3-inch) screen. Single targets are displayed as single spots of light. Land masses, coast lines, islands, etc., are displayed as relatively large patches of light having the general contour of the actual area being scanned. The distortion typical of B-type scans is present in the AN/APS–4 scope display. See figure 2–55.

A plexiglass filter located over the face of the indicator cathode-ray tube contains scribed vertical lines at intervals of 25° either side of the zero-degree or lubber line, to assist in judging target bearing. The position of the search aircraft is considered to be at the bottom of the central (zero degree) scribed line.

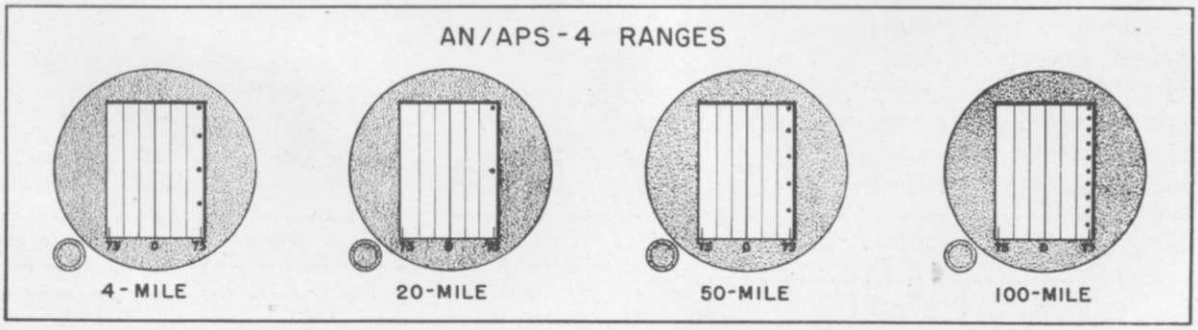
When set for beacon reception the AN/APS–4 indicators display the range-coded beacon signals to indicate the identity, range, and relative bearing of the beacon transmitter.

b. H-scan.—On intercept, the scope dislay, figure 2–56, is of the H-type scan. A target within the field of the antenna beam (150° in azimuth and 24° in the vertical plane) will produce an echo which appears on the indicator screen as two dots of light. The left dot is termed the echo pip, the right dot is termed the shadow pip. The position of the echo pip on the screen indicates the target's range and relative bearing. The position of the shadow pip relative to the echo pip shows the target's elevation. The intercept function of AN/APS–4 permits the interceptor aircraft to be maneuvered so as to put the target aircraft dead ahead and in the line of fire.

3. *Range settings.*—AN/APS–4 has four operating ranges which are identical for both search and beacon operation—4, 20, 50, and 100 miles. Range marks, instead of being horizontal lines of light as in other B-type scans, are a series of brilliant light spots which appear only at the extreme right vertical edge of the scope screen each time the antenna scanner reaches the limit of its sweep to the right. See figure 2–57.

Range (nautical miles)	*Number of range marks*	*Range mark interval*
4	4	1
20	2	10
50	5	10
100	10	10

Figure 2–57.—APS–4 has four operating ranges of 4, 20, 50, and 100 miles. The range marks produced by each of the ranges are shown above.



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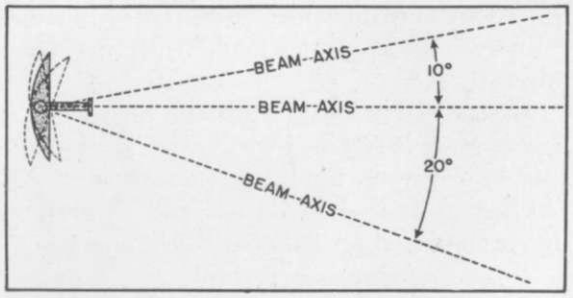


Figure 2–58.—The tilt of the APS–4 transmitted beam can be controlled manually from 10° above the horizontal to 20° below the horizontal.

C. Special features. 1. *Antenna tilt.*—By means of a control located on the panel of the control box, the antenna reflector may be tilted so as to cause the 6° beam to tilt from 10° above to 20° below the aircraft's line of flight. See figure 2–58. The nodding action of the antenna is independent of any setting of tilt. In other words, for any setting of antenna tilt, the antenna will execute a two-line, 4° nod on search, and a four-line 6° nod on intercept.

2. *Warning light.*—A warning light located on the control box may be set so as to flash when a target echo appears on the screen. During those periods when the operator may be unable to devote his entire attention to the indicator screen, the warning light may be set to indicate the presence of targets.

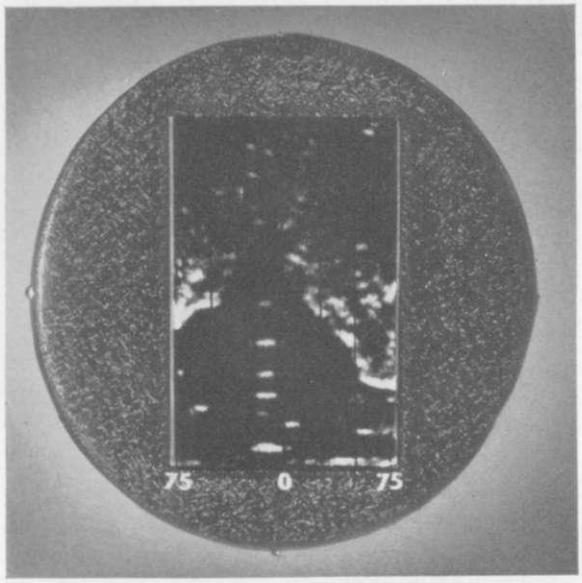


Figure 2–59.—Another view of the convoy proceeding up the bay as shown on the APS–4. Here the antenna has been tilted downward so as to focus the beam on the ship targets. As a result the land mass pattern loses some of its definition.

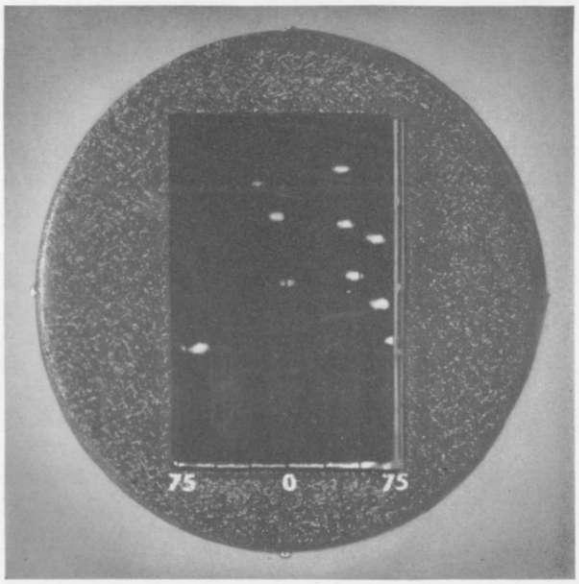


Figure 2–60.—Ships in convoy as seen on the 4-mile range setting of the APS–4.

III. TACTICAL EMPLOYMENT

A. Search; B. Navigation; C. Bombing. Tactically, the AN/APS–4 may be employed in the same way and for the same purpose as the AN/APS–3 (see p. 55) with the exception that the additional feature of intercept is provided.

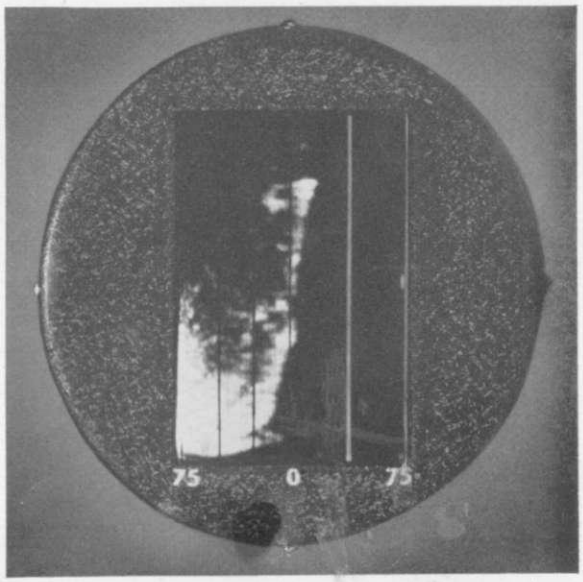


Figure 2–61.—Coast line as it appears on the 20-mile range setting of the APS–4.

D. Intercept. On intercept, the interceptor aircraft is maneuvered so as to get the target or echo pip on the central (zero-degree) lubber line with the shadow pip horizontally aligned with the echo pip. So long as the target aircraft remains in the field of the antenna beam the target pips will appear, regardless of evasive tactics employed. As the range is closed, both pips will move downward on the screen until visual contact can be made with the target aircraft.

Except under ideal conditions where the target aircraft is retained within the beam scan of 24° in elevation, the intercept feature of AN/APS–4 is limited in its use and as a rule is never employed for long periods of operation.

AN/APS-6

AN/APS–6 SERIES

NOTE.—AN/APS-6 and AN/APS-6A are identical in operation with the exception that AN/APS-6 is designed so that it may accommodate two indicator scopes instead of one as in the AN/APS-6A.

I. FUNCTION

A. PRIMARY PURPOSE. AN/APS–6 is an air-borne (night-fighter) radar designed expressly for the dual function of search and interception. It operates in the X-band of radar frequencies.

B. SECONDARY USES. AN/APS–6 on search develops a B-scan scope display which can be employed for purposes of navigation, i. e., making landfalls, recognizing land masses and islands, and selecting surface targets on which to home. It can also be used for radar beacon homing and (when suitable identification equipment is employed in connection with it) for the display of IFF signals.

II. DESCRIPTION

A. MAIN COMPONENTS. The main units of AN/APS–6 are:

1. Antenna scanner unit.
2. Transmitter-converter unit.
3. Indicator unit.
4. Control unit.
5. Auxiliary control unit.
6. Modulator.
7. Rectifier-power supply unit.
8. Receiver amplifier.

1–2. The antenna scanner unit with its associated transmitter-converter is faired into the right wing of the aircraft.

3–4–5. Inside the aircraft, the indicator unit is mounted in the instrument panel while the control unit and auxiliary control unit are mounted convenient for pilot operation.

6–7–8. All other units (requiring no adjustment or manipulation) are installed in remote sections of the fuselage.

B. ANTENNA SCAN AND SCOPE PRESENTATION. *beam coverage.*—On search, the antenna mechanism imparts an outward-inward spiralling motion to the rotating (1,200 r. p. m.) antenna scanner, to cause the 6° beam to cover a conical area of 120° ahead of the aircraft's line of flight. See figure 2–63. When the equipment is set to the gun-aim function, the spiralling motion is removed and the antenna revolves to produce a fixed cone of 15° along the aircraft's line of flight. See figure 2–64.

2. *Type of scan.—a. B-scan.*—AN/APS–6 when set for search, will produce a typical B-scan type of scope presentation, see B-scan, fig. 2–8), on its 25- and 65-mile operating range.

Depending upon the altitude of the aircraft and the range setting of the AN/APS–6 controls, surface and air-borne targets will be displayed in the normal B-scan manner if such targets are within the field of the spiralling beam. See figure 2–65.

b. O-scan.—When the range switch is set to either the 1- or 5-mile range, the scope presentation is automatically changed from a B-scan presentation to the O-scan or double-dot display. The O-scan presentation is employed mainly to display aircraft target echoes to indicate the relative range, azimuth, and elevation of the target. See figure 2–66.

Surface targets such as land masses, islands, ships, etc., if they are within the 120° field of

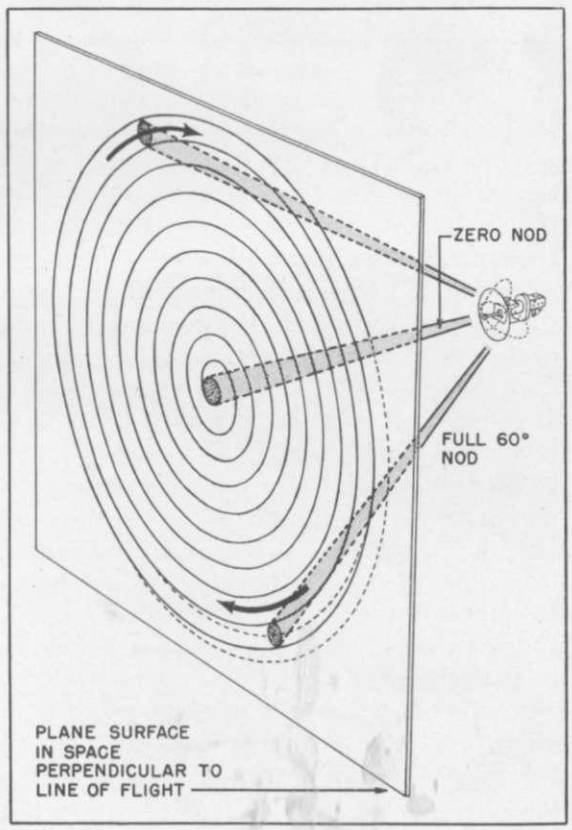


Figure 2–63.—When set for search, the APS–6 antenna spinner covers a conelike area of 120° ahead of the aircraft.

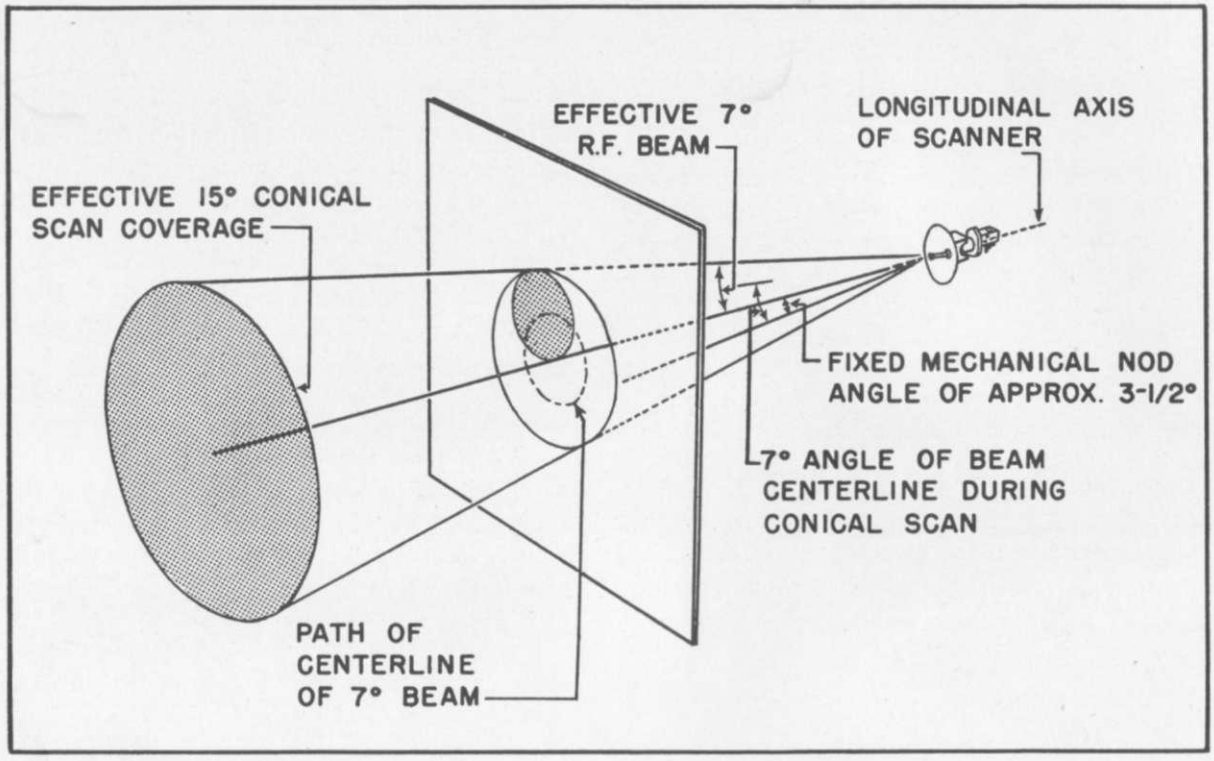


Figure 2–64.—When set for intercept, the conelike area is reduced to 15°.

the beam, will appear on the scope screen somewhat as in the B-scan type of presentation with the exception that all targets are resolved into the double-dot presentation and therefore will appear as an indistinct so-called double-exposure pattern. Other aircraft within the field of the beam will appear in the double-bot manner at their true azimuth positions on the screen.

c. G–scan.—When the auxiliary control is set from search to gun aim, the scope presentation is changed to a G-scan (see G-scan, p. 17). The target echo, which is represented as a single dot on the scope, will appear only when the target is within the beam at a range of 1,000 yards or less. The position of the spot with respect to the center of the scope face denotes the target's range (within 1,000 yards), its bearing and its relative elevation.

As the range between interceptor and target aircraft is closed, the target dot grows horizontal wings. When the interceptor aircraft is maneuvered to place the target spot at dead center, and the range is closed to make the tips of the wings touch the scribed index lines the target is bore sighted at a gun-firing range of 250 yards. See figure 2–67.

3. *Altitude mark and sea necklace.*—In addition to target echo display, two separate so-called sea returns are produced. One, a horizontal fuzzy line of light appearing upward from the bottom of the screen, is caused by direct reflection of echoes from the sea immediately below the interceptor aircraft. Its position varies with the altitude of the aircraft and provides a rough indication of absolute altitude. It is called the altitude mark.

The other sea return appears as indistinct, changing lines of light (commonly referred to as the "sea necklace," or "lace curtain"), arranged in a curved pattern which seems to hang from the top of the scope screen. It represents the return of echoes from the sea ahead of the aircraft, increasing and diminishing in size in step with the outward and inward spiralling motion of the antenna scanner. Its maximum-minimum size is a function of aircraft altitude and the range setting of the equipment. See figure 2–68.

In cases where target echoes above the sea return tend to become masked by the sea return, a "sea suppress" control enables the operator to cut out the central lower portion of the lace curtain.

4. *Range settings.*—The control unit contains a master range switch which allows the equipment to be set to any one of four operating ranges. They are 65 and 25 miles for search, 5 and 1 miles for intercept. When set for beacon reception, the same range settings denote ranges of 1, 5, 25, and 100 miles.

The auxiliary control unit contains a two-way toggle switch which throws the equipment from the 1- or 5-mile intercept ranges to the 1,000-yard gun-aim range. (When using the equipment for search or intercept, the auxiliary control toggle switch must be set to search.)

The AN/APS–6 scope is not furnished with a calibrated range scale. Target ranges for all four range settings must be judged with respect to the appearance of the target echo up from the bottom of the rectangular scope screen. See figure 2–69. The position of the interceptor

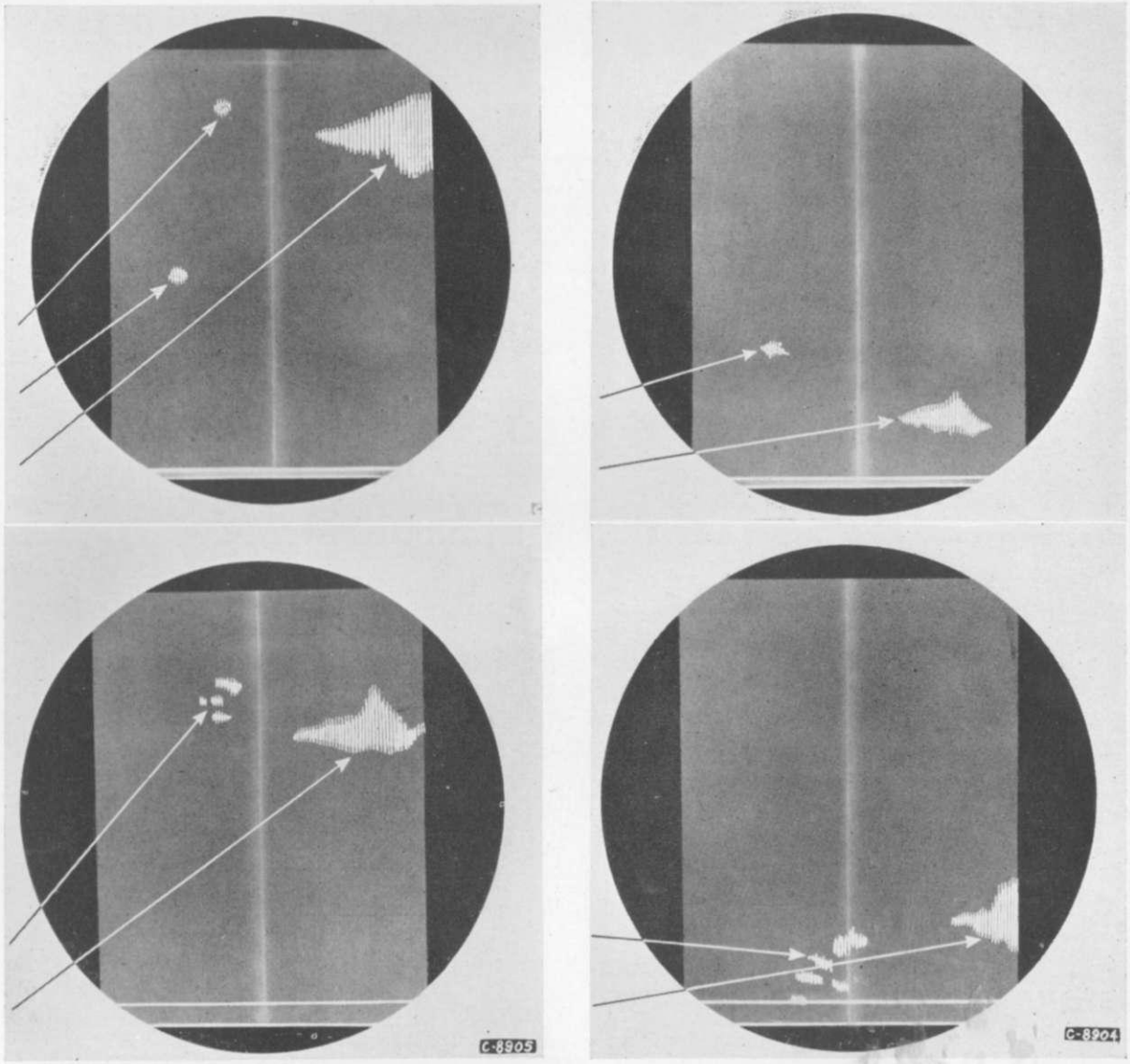


Figure 2–65.—APS–6 search patterns. Top, left, 65-mile range shows convoy, island and coast. Top, right, shows same convoy and island at 20 and 15 miles, respectively. Lower left, same targets on the 25-mile range. Lower right, 25-mile range. Lower right, 25-mile range; convoy at 3 miles, island at 8 miles.

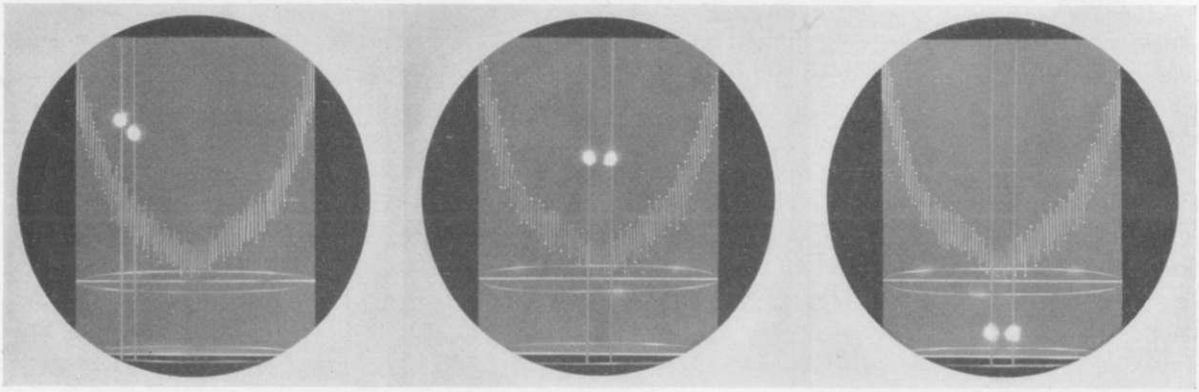


Figure 2–66.—On either the 1- or 5-mile range setting of APS–6 an "O" type scan presentation is produced. At the left the double-dot presentation shows that the target is about 40° port and below the intercepting aircraft. (Above, center.) The intercepting aircraft has been maneuvered to bring the target dead ahead. At the right the target is still dead ahead but the range has been closed.

aircraft is assumed to be at the lower center of the rectangular screen. The top of the screen represents ranges of 1, 5, 25, or 65 miles, depending upon the setting of the range switch.

For beacon-signal reception the maximum range is 100 miles.

C. Special features. Certain shortcomings in design and operation of the earlier AIA equipment (forerunner of the AN/APS–6 series) dictated the need for a more versatile night-fighter radar. The AN/APS–6 contains the required improvements, as follows:

1. The transmitter-converter unit is pressurized, permitting operation of the equipment at altitudes as high as 30,000 feet. (AIA was not pressurized.)

2. Location of the transmitter-converter in the radome, close to the antenna, permits the use of a short wave guide with a resultant increase in operating efficiency. (The AIA used a long wave guide from the antenna to the transmitter in the fuselage, which introduced signal attenuation.)

3. Four search-intercept operating ranges of 1, 5, 25, and 65 miles are provided.

4. Automatic frequency control of beacon tuning is provided. (In the AIA, tuning to beacon signals had to be performed manually.)

5. AN/APS–6 contains a wing calibrate adjustment which permits the pilot initially to adjust the size of the wings of the gun-aim scope presentation. The adjustment consists of flying the night fighter 250 yards behind a friendly plane (as determined by reference to the optical gun sight) and adjusting the size of the gun-aim wings on the target spot until the wing tips just meet the vertical lines scribed on the indicator face. (AIA did not contain this adjustment.)

6. In the AN/APS–6 B-Scan presentation, the separation of the double dots is such as to produce a sharp, easily definable indication of target elevation. (The AIA lacked a sensitive display in the double-dot presentation which made evaluation of target elevation difficult.)

III. TACTICAL EMPLOYMENT

A. Search. When specifically employed for search, AN/APS–6 enables the pilot of a night-fighter aircraft to observe all manner of targets within a wide area ahead of the aircraft up to the maximum range of the equipment. Large ships have been picked up as far away as 50 miles. Land targets are seen up to 65 miles in range, and aircraft are regularly seen to the limit of the 5-mile range.

B. Intercept. AN/APS–6, although suitable for use in general search operations, is particularly well adapted to night interception of hostile aircraft. When specifically employed for intercept operations of this nature, the fighter aircraft, after being air-borne, is vectored by the intercept officer at the controlling station (CIC of the fighter director ship or ADCC of the shore control station), to put the intercepting aircraft on the enemy's tail.

During the closing phase, the interceptor aircraft can employ the search function of AN/APS–6 on the 65-mile or 25-mile ranges to assist in picking up the target. When the range has been closed to within 5 miles, the range setting is switched to the 5-mile range and, as the range is closed to within 1 mile, to the 1-mile setting. On the 5- and 1-mile settings, the scope presentation presents the target in the characteristic double-dot style to indicate the target's relative range, bearing, and elevation.

When climbing or diving on a target, the latter may appear to be at the same elevation as the interceptor since it is in line with the inter-

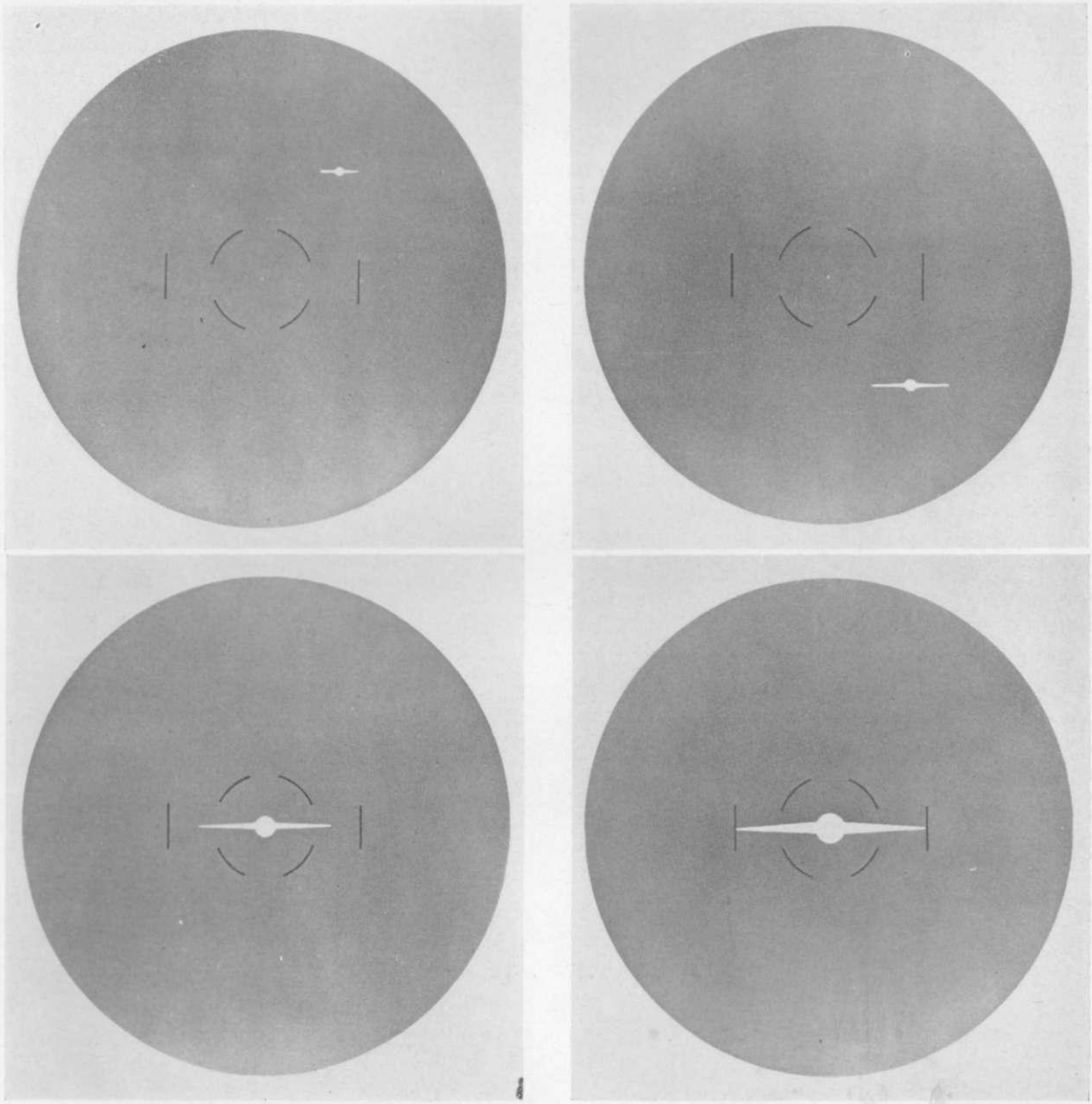


Figure 2–67.—When APS–6 has been set to the gun-aim function a type-G scope presentation is produced. The target image will appear as a small dot whose relation to the center of the scope indicates azimuth and elevation of the target. By maneuvering the aircraft the spot can be made to appear at the center of the scope. As the range closes the spot will grow wings. When the wings touch the scribed lines on either side of the horizontal center of the scope the target aircraft is at firing range.

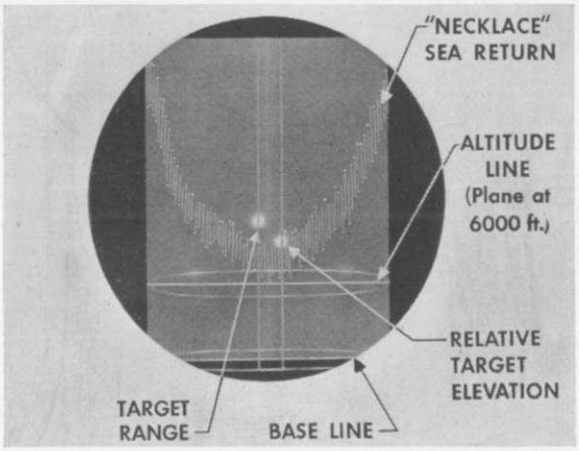


Figure 2–68.—As the spiralling motion of the APS–6 antenna causes the beam to strike the sea ahead of the aircraft, a series of reflections are returned to the aircraft which cause the characteristic sea return called "sea necklaces." Another series of reflections from the sea directly below the aircraft produces an "altitude line."

ceptor's longitudinal axis. However, because of differences in the course and speed of the two aircraft, prolonged maneuvers of this sort may result in: (*a*) moving the field of the radar beam off the target with consequent loss of target indication; (*b*) overshooting the target and disclosing the interceptor's presence, thus loosing the element of surprise; or (*c*) in the need for excessive corrective maneuvers requiring violent course and speed changes.

Climbing or diving maneuvers employed by the interceptor to put him on the tail of and at the same level as the target aircraft should be performed in steps, leveling off at the completion of each step to observe the target's new relative elevation.

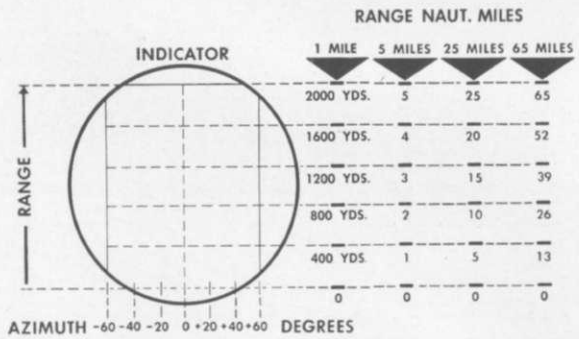


Figure 2–69.—The APS–6 can be set for any one of 4 ranges. The scope face, however, is not graduated in terms of range and target distances must be estimated as shown above.

C. Gun aim. The gun-aim function of AN/APS–6 should not be used until it is certain that the target aircraft is within 1,000 yards in range and at the same elevation as the interceptor. At 1,000 yards, or less, the target will be within the radar beam and its echo will show on the scope screen to indicate its relative range, bearing, and elevation.

If the range to the target should open because of too sudden decrease in speed of the interceptor aircraft or increase in speed of the target aircraft, or if evasive maneuvers of the target aircraft take it out of the conical beam, the spot of light will appear to snap quickly to the center of the screen where it will remain motionless. In such cases, the gun-aim switch must be set to search in order that the interceptor aircraft may again observe the target on the 1- or 5-mile intercept ranges and maneuver his aircraft into gun-aim range.

During the period of interception on either the 1- or 5-mile ranges, an attempt should be made to ascertain the target's speed so that the range may be closed gradually. Too fast an "overtake" may put the target aircraft out of the cone of fire, or it may result in actual collision.

D. Navigation. As is the case with other air-borne radars employing a B-scan scope pres-

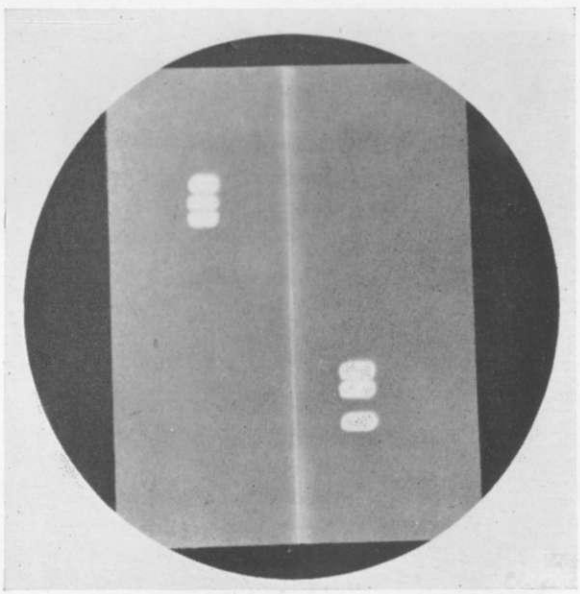


Figure 2–70.—Typical beacon coded signals, 100-mile range.

entation, radar navigation with AN/APS–6 is a matter of recognizing surface targets or land masses as such, and employing the information thus obtained for the purpose of navigating from one point to another, making landfalls, or establishing a course with respect to recognizable reference points.

AN/APS–6 displays targets according to the B-scan type of scope display only on the 65- and 25-mile ranges, when set for search.

When the equipment is set for radar beacon reception, the B-scan displays beacon signals (when within range of the beacon transmitter), as a series of range-coded spots which appear on the scope correct as to range and bearing. The coded arrangement of the signal presentation establishes the identity of the beacon transmitter. See figure 2–70.

GENERAL APPLICATIONS OF RADAR

I. INTRODUCTION

Because they lend themselves to a diversity of uses other than those for which they were primarily designed, air-borne radars have become one of the most effective of tactical weapons. Even under the most perfect of flying conditions, the information they are capable of providing is often superior to that obtained by visual means; in other cases, radar becomes a valuable source of supplementary information with which to cross check information received visually. Under adverse conditions of reduced visibility or total darkness, radar is often the only source of information available to pilot, navigator, and bombardier.

Regardless of the specific purpose for which a given air-borne radar has been developed, there are certain factors concerning its tactical employment which are common to all air-borne radars. The following section describes certain features of operation and employment which apply generally to all search-type air-borne radars.

II. RECONNAISSANCE AND PATROL

A. GENERAL. 1. *Conditions of visibility.*—Radar is especially effective under conditions of low visibility, but even in good weather it should be used at all times for search. Though it is true for practical purposes that, with visibility unlimited, the human eye can reach out nearly as far as the radar, it is not true that the human eye can give as efficient coverage of an area.

Small targets that blend with the color of the sea are likely to be missed by the eye, but the ability of radar to detect targets is not affected by camouflage. Targets into the sun are difficult to see, particularly when the sun is low on the horizon; and a slight haze sometimes cuts down visibility without being noticed by the crew. Radar functions regardless of conditions of visibility. Visual search depends upon the continued alertness of the aircraft's crew at all times; radar will detect targets whenever they are within radar range. On the other hand, crew members should not abandon visual alertness because of the use of radar. The two, used together, insure the most efficient coverage of an area during search.

2. *Range.*—The factors which affect range are: (*a*) altitude, (*b*) power, and (*c*) to a limited degree, equipment break-down ceilings.

a. Altitude.—The maximum effective range of the radar equipment will be dependent upon the aircraft's altitude relative to the range settings of the equipment. In other words, even if a radar is set to operate on its 100-mile range, it will not be able to detect targets at this range when its flight altitude is so low that the radar horizon extends only to a maximum of 50 miles. The chart, figure 2–17, on page 19 gives the radar line-of-sight distances to the horizon for various altitudes.

b. Power.—The power of an air-borne radar equipment constitutes one of the prime factors which limit operating range. Echo reception at long ranges is dependent upon the ability of the equipment to transmit pulses which will be powerful enough to cover the distance from the radar to the target and to produce an echo of sufficient strength to complete the return trip. In this connection, therefore, once the maximum range as defined by the power limitations of a particular radio equipment itself has been reached, a further increase in range will not be effected merely by increasing the altitude of the searching aircraft.

c. Radar equipment operation ceilings.—Because certain parts of air-borne radars operate at extremely high values of voltage and are subject to electrical break-down at the low atmospheric pressures encountered at high altitudes, pressurizing safety precautions have been incorporated in the design of some equipments to maintain them at pressures comparable to those at the safe operating altitudes. The altitude limitations or "break-down ceilings" for the several types of air-borne radar equipments are listed in column 8 of the table on page 145.

B. AREA SEARCH. In planning radar search operations a medium range setting of the equipment should be chosen so as to insure adequate echo reception from small targets. The altitude at which the search aircraft is to be flown in order to provide this range coverage should

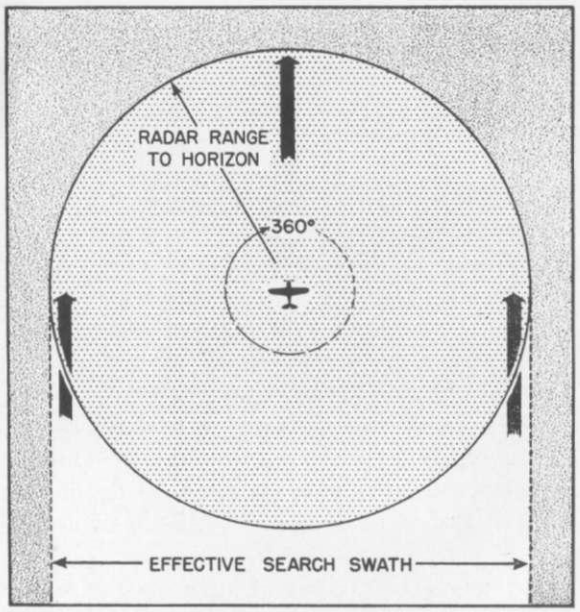


Figure 2–71.—In conducting a search operation with the PPI type of radar equipment, the effective swath of an air search leg is determined by the altitude at which the aircraft is flying and its radar range to the horizon.

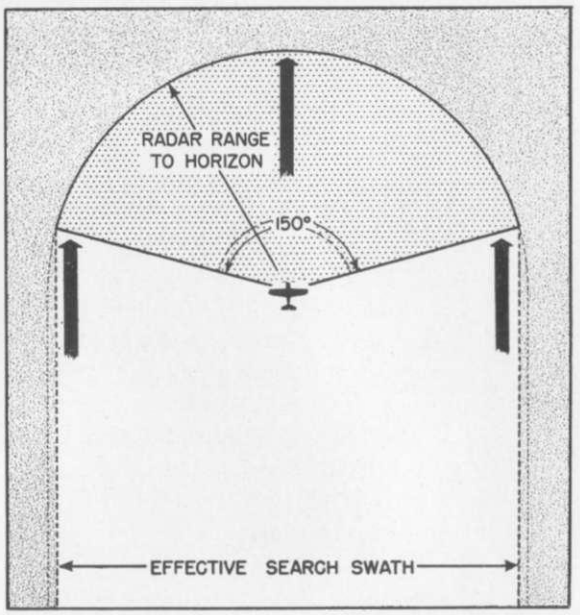


Figure 2–72.—In aircraft equipped with radars employing the B-type scan, only the area immediately forward and to the sides of the aircraft are scanned, as shown here. Because of the 150° sector scan, the actual search swath is somewhat less than the search swath area produced with the PPI type of equipment. However, here, too, the effective width of the search leg is determined by the altitude of the aircraft and its radar range to the horizon.

be high enough to insure that the radar horizon is just slightly beyond the maximum range employed.

The search aircraft, if equipped with either the L-type or PPI-scan radar will sweep a search swath whose width will be twice the effective range of target detection (see fig. 2–71). In laying out area searches when using the B-scan type of equipment, however, it must be remembered that here the scanner sweeps an area extending only to 75° either side of the dead-ahead position. This results in a search swath which is somewhat narrowed in width (see fig. 2–72). The swath thus produced by the field of coverage (making allowances for a certain amount of overlap) will dictate the number of legs to be flown in order to cover a specified search area.

For example, a search mission may involve the use of an aircraft fitted with AN/APS–3 search radar. Consistent, reliable target pick-up, it may be found, is obtained on the equipment's 40-mile range setting. The line-of-sight table (p. 19) indicates that an altitude of 1,000 feet will produce a radar horizon at a distance of about 38 miles. This is safely within the 40-mile range setting. A conservative range at which a wide variety of targets will be displayed by the equipment is about 35 miles. This is still within the 38-mile radar horizon. Allowing for the fact that the oscillating antenna sweeps through 150° of arc (75° each side of dead ahead) and thus does not cover the full 35-mile distance either side of the aircraft, the maximum side area may be considered to be approximately 10 percent less or about 31.5 miles. This means that the air-borne radar is safely covering an area ahead and to either side of the aircraft to a distance of approximately 31 miles. If the search area to be covered is some 360 miles on a side, then allowing for a small amount of overlap for successive legs, some six legs will have to be flown, in order to cover the entire area. See figure 2–73.

In cases where patrol craft are equipped with loran, the problem of area search is greatly simplified if full use is made of the loran charts in laying out the various legs of a search area (see Tactical Employment of Loran, p. 140).

C. Sector search. Planning sector searches involves the employment of the same planning procedure as for that of area searches. The maximum range of detection is estimated for the types of target expected, and the appropriate flight altitude is determined for such range.

In addition, however, the sector search depends upon meeting the coverage requirements—

1. *Where the sector angle is specified:* The length by the sides of the triangle will be determined by the search swath of the air-borne radar.

2. *Where the distance to be flown from carrier or base is specified:* Keeping in mind the restrictions imposed by the search swath area, a sector angle must be chosen to provide complete coverage of the sector search area.

Figure 2–74 illustrates condition 1, wherein for a given sector angle the range from base must be calculated to avoid excessive overlap on the one hand and an uncovered area on the other.

Figure 2–75 illustrates condition 2. Note that for a given distance from carrier or base the sector angle must be such that complete coverage of the area may be accomplished.

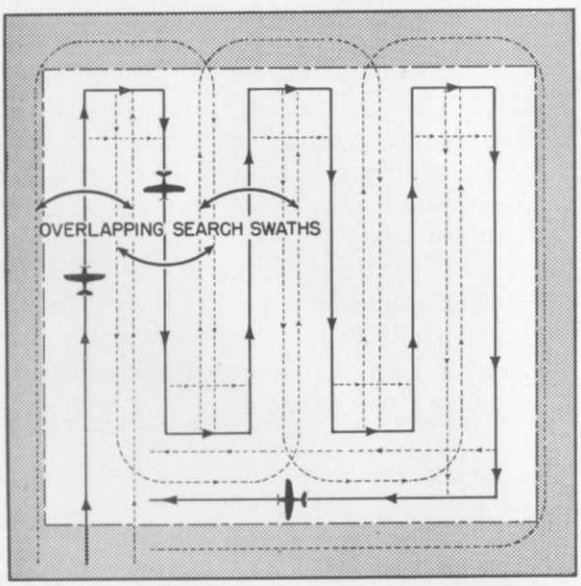


Figure 2–73.—When planning a search of a specified area, consideration must be given to the width of the search legs so that the number of legs to be flown can be calculated to adequately cover the entire area, allowing for a slight amount of overlap between adjacent legs.

D. Antisubmarine search. This type of search proceeds much as any other except that the assumed radar horizon will be less and the searching altitude lower. At close ranges, most radars can detect submarines when only their periscopes show.

Because it is possible for submarine targets to detect the presence of search aircraft by tuning in on the radar pulses, it is advisable, once an unidentified target is detected, to employ the search radar intermittently.

III. NAVIGATION

A. Drift. 1. *Drift compensation methods.*—When an aircraft is directed toward a target

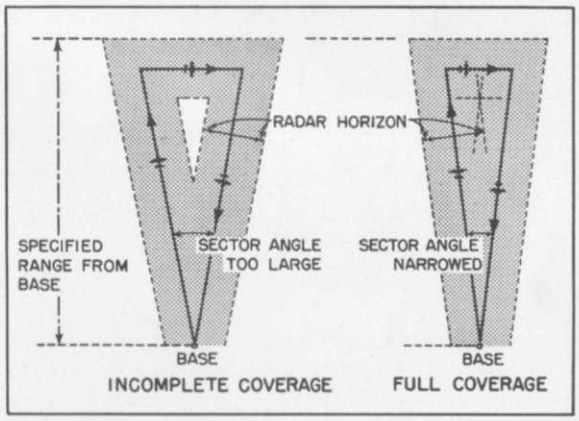


Figure 2–74.—Where a given sector angle for a search is specified in the operating plan, the altitude of the aircraft and the length of the legs must be determined to provide a search swath which will adequately cover the area to be searched without producing incomplete coverage.

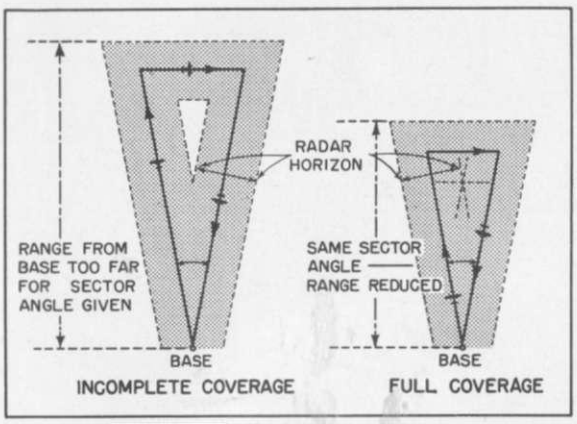


Figure 2–75.—Where the range of a given area is specified, the altitude of the aircraft and the angle of successive legs must be determined to provide a search swath which will adequately cover the area to be searched without producing incomplete coverage.

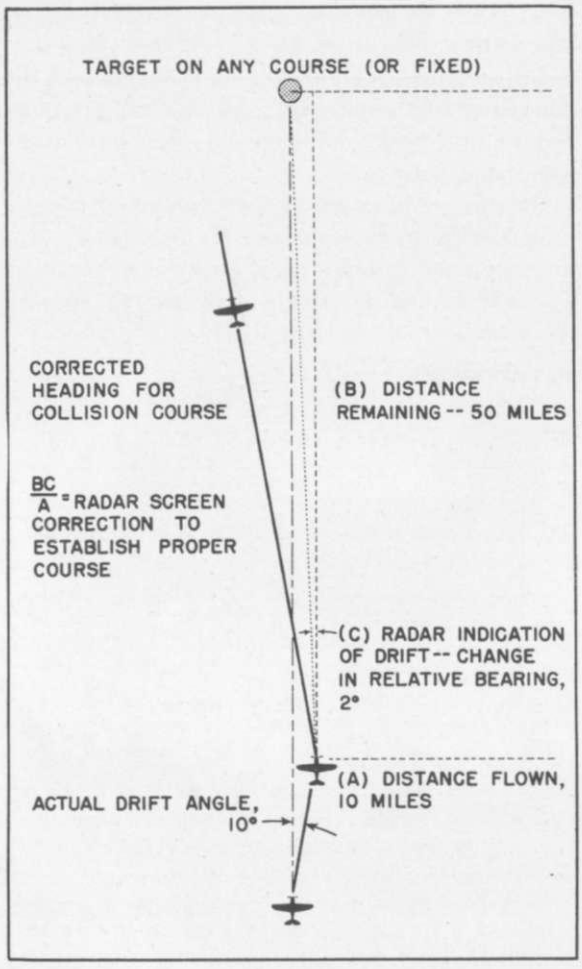

TARGET ON ANY COURSE (OR FIXED)
CORRECTED HEADING FOR COLLISION COURSE
(B) DISTANCE REMAINING -- 50 MILES
BC/A = RADAR SCREEN CORRECTION TO ESTABLISH PROPER COURSE
(C) RADAR INDICATION OF DRIFT -- CHANGE IN RELATIVE BEARING, 2°
(A) DISTANCE FLOWN, 10 MILES
ACTUAL DRIFT ANGLE, 10°

Figure 2–76.—A method as described in the text for determining correction for drift by radar.

and the heading is thereafter held constant, a gradual change in the bearing of the target echo as observed on the scope indicates drift. If the echo moves to the left of the lubber line, the aircraft's drift (not the target's drift) is to the right, and vice versa. The direction of drift is easily determined, but compensating for drift is more difficult.

Two radar drift compensation methods are described, as follows:

a. Method 1.—To determine the amount of drift, a radar target is selected and the aircraft is maneuvered so as to place the target on the lubber line, preferably near the top of the scope screen, and the range to the target is noted. Then for a selected distance, the course is maintained, during which time (if drift is present) the target, in addition to moving down the screen, will also move to one or the other sides of the lubber line, depending upon the direction of drift. By multiplying the observed drift in degrees by the distance in miles yet to be flown to intercept the target, then dividing the product by the distance flown during the check period of observation, a result, in degrees, will be obtained which indicates the required change in heading that must be made in order to compensate for drift and to maintain a collision course with the target. (See fig. 2–76.)

b. Method 2.—(This method is not adapted to L-scan (ASB) radar equipment.) If an aircraft is headed directly toward a target and a constant course maintained, drift causes the radar echo to change in bearing. The amount of change depends upon the range at which the aircraft was first headed toward the target and the distance subsequently traveled. By employing the graph (fig. 2–77), the angle of drift can be determined.

The procedure for using this graph is as follows:

(1) Note the range when the target is dead ahead.

(2) Maintain this heading until the target has changed in bearing by 5°. Then note the target's new range.

(3) Along the bottom of the graph, locate the vertical line corresponding to the range at which the 5° drift was indicated. Then along the left edge of the chart locate the horizontal line corresponding to the initial range noted.

(4) At the point of intersection of the selected horizontal and vertical lines the drift angle is indicated by the degree line that passes through this point of intersection or by an interpolated line estimated by eye to the nearest whole degree.

As an example of the use of this chart: A target is observed dead ahead at a range of 40 miles. A constant heading is held until the target has changed by 5°. At this point, the range to the target has closed to 25 miles. Employing the graph, the 25-mile vertical line along the bottom of the graph is selected, and along the left edge of the graph a horizontal

line corresponding to the original 40 miles is located.

It is found that these two lines intersect at a point on the graph which is crossed by the 8° drift line. This indicates the aircraft's angle of drift.

The successful use of this method depends upon the operator's ability to read fairly accurately a bearing of 5° to left or right of the zero-degree line. With the AN/APS–3, the expanded sweep should be employed and the flashing lubber line set to 5° left or right, depending on the direction of drift. As soon as the echo is centered under this flashing lubber line, the second range reading is taken.

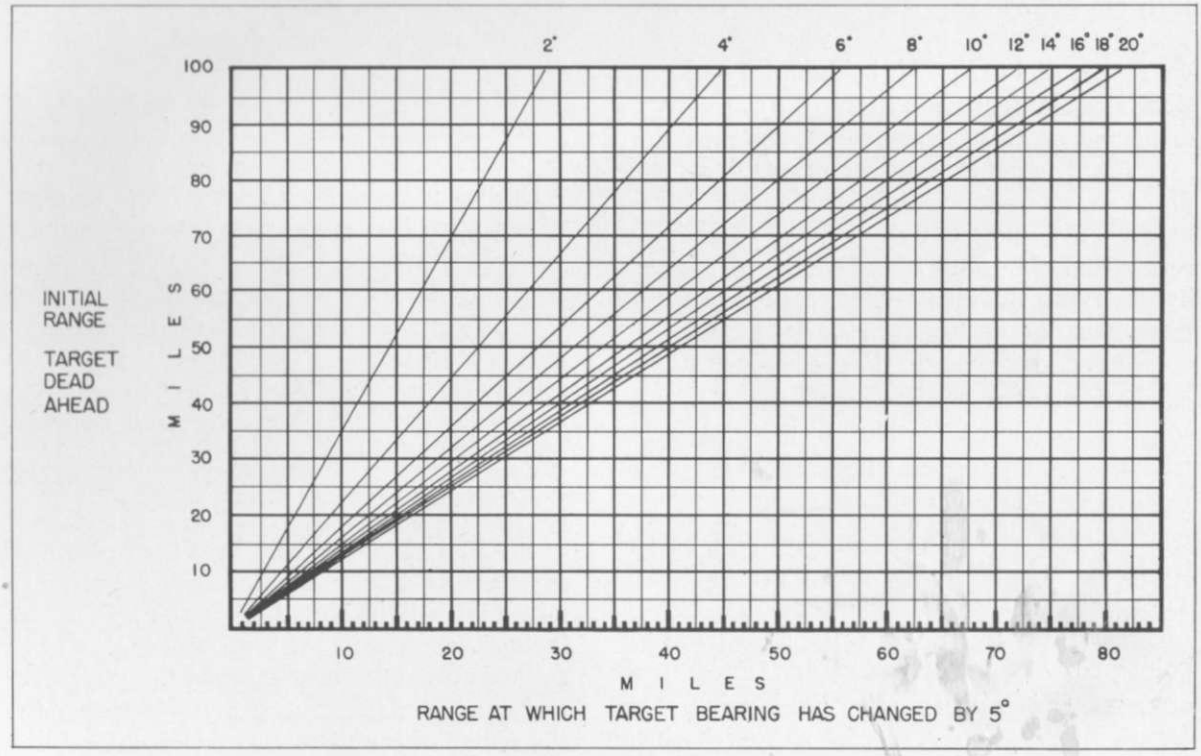
With the AN/APS–15, the aircraft is maneuvered until the target echo is placed dead ahead. The direction in which the echo drifts is noted and the scribed azimuth index line is rotated 5° in the direction of drift. Again range is noted as soon as the target is centered under this new position of the azimuth index line.

With map-type radars that do not have a flashing lubber line or a movable azimuth index line, the 5° position must be estimated. On all map-type radars, it is necessary to use the center of the echo as the point from which to determine the bearing. A broad land mass is not a suitable target unless it has a projection or indentation that produces a radar target which may be employed as an easily noted point of reference.

Ship targets are not reliable for determination of drift since a change of bearing may be caused either by wind or ship motion or both.

2. *Surface wind checks.*—There are many times during flight over open water when no targets are in sight. In such cases, the two methods of drift determination above described cannot be successfully employed, since they require the use of a fixed target. With certain radars, however, an experienced operator can make a fair estimate of the direction of *surface* wind and a very rough estimate of its velocity, provided the aircraft is at an altitude of about 1,000 to 1,500 feet. Because winds at higher altitudes may differ from near-surface winds, the information obtained is of value only for low-altitude flights.

Figure 2–77.—Another method for determining drift by radar is through the use of this chart, as described in the text.



Since the wind at and near take-off point is usually known, the size and appearance of the sea return should be observed closely as soon as the aircraft is at flight altitude and on course. Subsequent changes in both direction and intensity of the wind produce changes in the appearance of the sea return on the scope screen. This change takes the form of an enlarged sea return on the upwind side because the larger surface of the waves present a greater reflecting area to the transmitted pulses of the radar. With practice, such changes in sea return pattern can be interpreted to indicate roughly wind direction and velocity.

B. Absolute altitude. On most radars the sea or ground return can be used to indicate an aircraft's approximate absolute altitude, the degree of accuracy obtainable varying with the type of radar used. As a general rule, none are affective for this purpose when the absolute altitude is less than 1,500 to 2,000 feet. For this reason, radar altitude acts best as a check upon having sufficient margin of safety when flying over mountainous territory.

C. Coastal navigation. 1. *Pilotage.*—Following a coast line is quite easily accomplished with the aid of radar and a map of the area. The screen pattern indicates whether or not a course parallel to shore is being flown and position is established from shore line contours, as displayed on the scope.

2. *Point-to-point navigation.*—On a long flight, point-to-point radar navigation can be used. This means flying a predetermined course and obtaining radar checks of position by observing the identifying characteristics of prominent landmarks such as headlands, harbors, bays, and rivers. Normally, such flights can be flown at great distances off shore. Point-to-point radar navigation is used also for island-to-island flights where an objective is reached by following a string of islands.

This type of navigation requires accurate tracking of the flight and careful map reading. To avoid the possibility of losing the identity of a check point, the ETA for each point-to-point jump should be computed. Unless there are several headlands or other check points close together, the ETA can serve as a cross check on the radar information so as to make identification positive.

When making an approach from the open sea to an island dead ahead, it usually is unwise to head directly in and then make a 90° turn to follow the coast line, because mountains on the island or an enemy garrison may make such an approach dangerous. Rather, the approach should be made tangentially; that is, at a range of from 4 to 5 miles from the island, a 45° turn is made in the desired direction. When the aircraft has closed to the desired distance off shore, another turn is made to place its heading parallel to the coast line.

3. *Pin-point radar navigation.*—When accurate radar coastal fixes are required or when a radar approach is made to a specific objective, the aircraft should be flown close to the shore and at low altitudes. The range setting of the radar should be such that the target and the immediate area about it covers a substantial part of the scope screen. Optimum conditions for accurate work are about 1 mile off shore and 1,000 feet in altitude. Under these conditions, pin-point radar navigating for mine laying, bombing, or approach of landing can be done. Where possible, the approaches should be planned in advance with adequate attention being given to photo-reconnaissance reports and the use of landfall relief maps so that the objective as displayed by the radar can be readily identified.

D. Mine laying. Mine laying at night, where accurate ranges are essential, requires pin-point navigation. Since mining operations usually take place at channel entrances, accurate piloting is required. With the map-type radars (particularly the B-scan type), the actual approach is relatively easy, provided the radar navigation is carefully and accurately planned in advance.

When radar mine laying is conducted by several aircraft it is advisable for the operator in the lead aircraft to perform the radar navigation for the section, all aircraft releasing the mines on a light signal from the leader, thus laying the mines in pattern. The timing of the release must take into account the disposition and spacing of the aircraft in the section so that the center of the pattern is midchannel.

The method of determining the release point depends both upon the type of radar and the topography of the particular area being mined. If the topography is suitable, the drop is made at a given distance from a point ahead as displayed by the radar, such as the opposite bank of a channel, coral reefs known to jut above the water, or even from channel markers. Under other conditions, it may be necessary to make the drop a certain number of seconds after passing a radar check-point on the required heading. With the map-type radars, a series of photographs of the radar screen taken during a "dry run" by reconnaissance aircraft will prove invaluable for planning mining operations.

IV. RADAR BOMBING

Radar bombing techniques vary widely according to the tactical situation, the type of radar, and the type of aircraft employed. Such bombing may be carried out partly by radar and partly visually; it may be accomplished using the search radar only; or search radar with bombing attachments may be employed. It may involve precision bombing against ships at low altitude; area bombing of enemy bases at medium altitude; or pattern bombing of cities at high altitude.

There are two main radar problems in bombing. The first is the problem of flying a collision course to intercept the target. The second is the problem of accurately ranging on the target to determine the correct release point. At low altitude or high altitude, these problems are essentially the same.

A. Low altitude bombing. 1. *Target approach.*—The manner in which attacking aircraft approach the enemy depends on many things—disposition of the enemy force, visibility, possibility of interception by enemy night fighters, and other elements that enter into the total tactical situation.

In approaching an enemy task force or convoy for a radar bombing attack, it is usually the case that the ships upon which the attack is to be made are inside a screen of escort ships. It becomes important, then, that the approach be made in such a way as to enable the radar to furnish maximum discrimination between targets so that any given target within the group may be singled out and attacked. Usually it is desirable to approach a selected radar target within a screen in such a manner that the aircraft does not pass close to a screening vessel. The disposition of the ships should be noted beforehand and the approach made so as to avoid these escorts.

If, at long range, target course can be determined, a beam approach may be possible. Under such conditions, the size of a target can be fairly accurately estimated. Should the approach be modified to suit drift conditions or enemy disposition, the final run should be made at a minimum of 3 miles in order to accurately set up a collision course which can be observed by radar.

The altitude of approach, once radar contact with the enemy is established, varies with the tactical situation. To avoid detection by enemy radar over sea areas, a close-to-the-water approach up to about 20 miles should be made, after which correct bombing altitude is regained.

Assuming the enemy can track an approaching aircraft with his radar, a straight-in-approach has the disadvantage of letting the enemy know the aircraft is heading directly for him. At this point, a certain amount of deception may be employed to advantage.

Basically, these deceptive measures involve:

(*a*) If possible, locating the enemy at a radar range of 10 miles or more.

(*b*) Setting a course that will allow closing with him but will leave him in doubt as to whether an attack is developing.

(*c*) Turning in to the attack at the last moment, allowing just enough time to establish a collision course for an accurate radar bombing run.

2. *Release point.*—Low- or high-altitude bombing demands a range precision that is difficult to obtain with search radars not equipped with special bombing attachments. Somewhat of an exception is the ASB radar with which it is possible to determine the release point within approximately 100 feet. The map-type radars have an inherent error introduced by the time interval between successive sweeps of the scanner across the target. This has the effect of

making the target come down the screen by "steps" rather than continuously. Successive scanner sweeps may display the echoes as much as 100 to 500 yards apart, depending upon the scanning speed. As the aircraft nears the release point, the step effect becomes a serious drawback, This, along with other inherent difficulties of reading accurate ranges close to the target, indicates that the degree of precision necessary for accurate bombing is neither easily nor reliably obtained from the search radar alone.

3. *Torpedo attack.*—A knowledge of the target's course and speed is necessary before torpedo attacks are effective. Since radar cannot furnish this information with a reliable degree of accuracy, visual assistance becomes necessary. The radar has a definite use, however, in detecting targets at long range and assisting in making the approach. For the torpedo run, once visual contact is made, radar can be employed to furnish reliable range information which can be used to assist in determining the torpedo release point.

4. *Accuracy of low altitude bombing.*—A radar attack presumes that a target cannot be seen visually and therefore, unless target course can be determined, it is difficult to distinguish between length and beam of a ship from its echo on the screen. This introduces two errors in the low-altitude bombing problem—(*a*) deflection errors and (*b*) range errors.

a. Deflection errors.—The relative importance of these errors depends largely upon the angle from which the approach to the target is made. In other words, target width is a function of target length and target angle. For example, figure 2–78 shows the effects of approaching from different angles a ship 500 feet long with 60-foot beam. The illustrations show the angular width as seen from a bomb-release point of 400 yards. The allowable error in the collision course is obtained by taking one-half the angle which the outside limits of the target form as seen at the release point. From a study of the illustrations, it is obvious that a beam approach increases the allowable deflection error.

b. Range errors.—Allowable range errors depend upon the target's depth in the line of flight. This, in turn, depends upon target angle. Suppose, with a target having a freeboard of 40 feet and a beam of 100 feet, the approach is made broad on the boam.

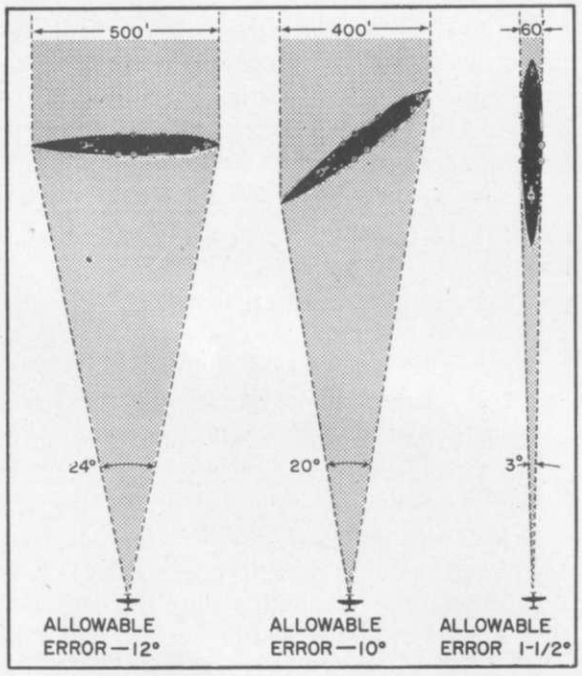


Figure 2–78.—From a bombing standpoint target width as observed on a radar scope is a function of target length and target angle. The above figure illustrates that a beam approach to a target increases the allowable deflection error which is an important factor in the successful outcome of radar bombing.

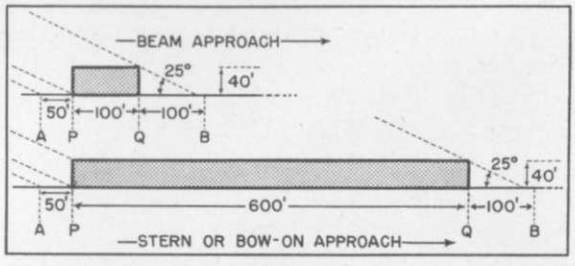


Figure 2–79.—From a consideration of the above figure it will be seen that the range errors are most critical when making a beam approach. It will be seen that by making a radar approach on a target's beam the element of range error becomes quite critical whereas range error is low for a stern or bow-on approach. Of course, such approaches assume that the radar scope presents information which allows the target's course to be determined, thus making a beam approach or a stern or bow-on approach a matter of choice by the pilot.

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It is known that a bomb released from 300 feet at 180 knots enters the water at an angle of about 25°. Assume as a hit any bomb that lands between points "A" and "B," figure 2–79. By simple mathematics it is found the "QB," for this example, is about 100 feet and gives a total hitting space of approximately 250 feet in the line of flight. Suppose, however, the approach to the target is made from the stern. "PQ" now becomes the length of the ship and the hitting space increases to approximately 750 feet. This example illustrates the obvious fact that range errors become critical when approaches are made broad on the beam.

c. Sources of error.--Deflection and range errors can be attributed to three causes (assuming level flight at the instant of release):

(1) Errors in the radar range, caused by limitations inherent in the radar, possible faulty calibration, and poor interpretation by the operator.

(2) Miscalculation of speed with which the aircraft approaches its target.

(3) Improper altitude at the instant of release.

For any particular bombing run, the errors due to (1) cannot be compensated for.

For (2) and (3) the following must be considered: Deflection errors are less critical for a beam approach to a target than for a head-on or stern-to approach. Range errors on the other hand, are less important for approaches to targets head-on or stern-to than for beam approaches. Range errors can be compensated for in large measure by dropping bombs in train.

B. High-altitude bombing. From a radar standpoint, high-altitude bombing (10,000 to 40,000 feet) requires the use of radars suitable for such work, or parent radars with requisite bombing attachments in order that the required degree of bombing accuracy may be obtained.

As has been stated previously, the problem of high-altitude bombing is essentially similar to that of low-altitude bombing except that the manner of accomplishment does not ordinarily require observance of all of the factors inherent in low-altitude bombing.

Because high-altitude radar bombing requires the use of specific radar equipments or attachments, their mode of use will dictate the manner in which the actual bombing run is to be accomplished. (See AN/APS–15, p. 41, and AN/APQ–5B, p. 91.)

AIR-BORNE TAIL WARNING RADAR

I. TYPES AND FUNCTION

There are four separate sets of air-borne radar equipments which are designed for the specific purpose of warning aircraft personnel when other aircraft are at close range astern. These equipments, called tail-warning equipments, are:

(For installation in fighter planes)	*(For installation in patrol bombers)*
1. AN/APS–11	3. AN/APS–16
2. AN/APS–13	4. AN/APS–17

A. AN/APS–11, AN/ASP–13. The AN/APS–11 and AN/ASP–13 are similar except for differences in the electrical circuit arrangement. These radar equipments convert reflected energy from aircraft targets to the rear of the fighter aircraft into an electric current which turns on a red light located near the gun sight and so shielded as not to interfere with other lights on the instrument panel. The red light warns the pilot that another aircraft is within the cone of coverage of the equipment (90° wide in a vertical direction and 60° wide in a horizontal direction) and within a range of 200 to 800 yards.

The maximum range of 800 yards was purposely kept low. At ranges greater than 800 yards, the pilot is in no immediate danger from a tailing plane. Within that distance, however, evasive action becomes necessary if the tailing plane proves to be hostile.

B. AN/APS–16, AN/APS–17. The AN/APS–16 and AN/APS–17 are similar to each other but differ from the AN/APS–11 and AN/APS–13 in range and in the indications they produce. Intended for use in bombers, they are designed to warn the entire crew.

1. In the AN/APS–17, returning echoes from an aircraft astern produce a 1,000-cycle note that is pipped or interrupted at a rate inversely proportional to the range, from 1 pip per second at 3,000 yards to 10 pips per second at 200 yards. In other words, as the range between the two aircraft closes, the repetition rate of the signal pip increases. The warning signal is fed into the interphone system, thus warning all crew members at the same time.

The maximum range is adjustable from 500 to 3,000 yards. The fixed antenna produces a beam whose coverage is a cone 120° wide.

2. The AN/APS–16 has the same range and beam coverage as the AN/APS–17. The indication is a 400- to 1,400-cycle note which, since its power comes from the aircraft's generators, will vary in pitch with the r. p. m. of the aircraft's engines. The tone is interrupted at a rate inversely proportional to range, from 2 pips per second at 5,000 yards up to 10 pips per second at 200 yards.

C. Limitations of tail warning systems. 1. One disadvantage in the use of the system lies in the fact that friendly escort planes trigger the warning system into operation every time they fly on or across the tail of the tail-warning-equipped bombers. To surmount this difficulty, the inclusion of identification equipment will make it possible to differentiate between friendly and enemy aircraft.

2. Another disadvantage which is common to all tail-warning equipments is that when the aircraft is flying at low altitudes (at an altitude within the horizontal range of the equipment), the sea or ground return produces a spurious warning signal which could be mistaken for a tailing aircraft. Recommendations have been made to sufficiently alter the design of tail warning equipments so as to eliminate this disadvantageous effect.

CAPACITOR UNIT
MX-139/APA-16
RANGE MARKER UNIT
SN-12/APA-16
CONTROL UNIT
C-106/APA-16
MODIFICATION KIT
MK-22/APA-16
OPERATING
HANDBOOK

AN/APA-16

ASSOCIATED EQUIPMENTS

(Bombing Attachments and Airborne Fire Control Radar)

AN/APA–16

I. FUNCTION

The AN/APA–16 is a low-altitude radar bomb sight, designed to facilitate the bombing of surface vessels from aircraft. It operates, in conjunction with parent radars such as the ASB Series, the AN/APS–3 (ASD–1), and the AN/APS–4 (ASH), to compute the release range to a target and to automatically release the bomb when the aircraft reaches the release position.

II. DESCRIPTION

The AN/APA–16 assembly comprises three major units. They are:

1. Control unit.
2. Range marker unit.
3. Capacitor unit.

In addition, a modification kit is required to adapt the AN/APA–16 to the particular radar installation employed.

III. MODE OF OPERATION (*for example, with ASB radar*)

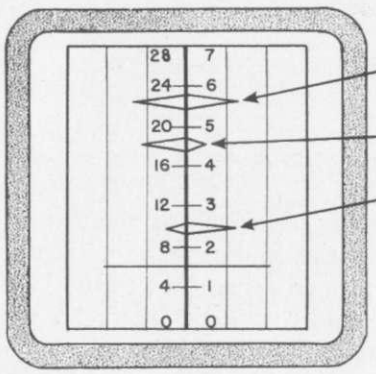
In explaining the general operation of the AN/APA–16, it is assumed that the echo signal from the target which it is desired to bomb has been located on the screen of the radar indicator.

The AN/APA–16 attachment is triggered from the radar trigger pulse and supplies pulses to the ASB indicator for tracking a selected target and for indicating the release range. The resulting presentation on the ASB indicator screen is in the form of a blanked-out section of the sweep trace. This blanked-out part of the trace is called the range mark. It causes the screen to present an appearance like that of "B" in figure 2–80, or, under conditions of adjustment, like those of "C," "D," or "E."

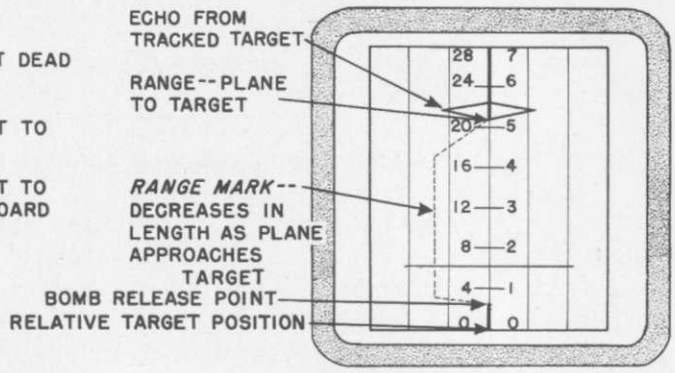
The leading edge of the range mark, the end nearest zero range, indicates the bomb release range; the lagging edge of this pulse can be set coincident with the leading edge of the echo pulse and, by proper adjustment of the control unit, can be made to "track" the echo pulse, under which condition the computer in the control unit is supplied with the required information as to the relative velocity between the aircraft and the target. The release point is a function of the relative velocity between aircraft and target and the altitude of the aircraft, and is computed by means of electrical circuits.

As the aircraft approaches the target, the blanked-out portion of the indicator sweep between the echo signal from the chosen target and the bomb release point grows shorter and shorter and disappears when the release point is reached. Short sharp pulses coincident with the leading (release range) edge and with the lagging (tracking) edge of the blanking or range marker pulse are also developed in the AN/APA–16 attachment. When these pulses become coincident, as they do on arrival of the aircraft at the release point, they act through a coincidence circuit to actuate the bomb release mechanism.

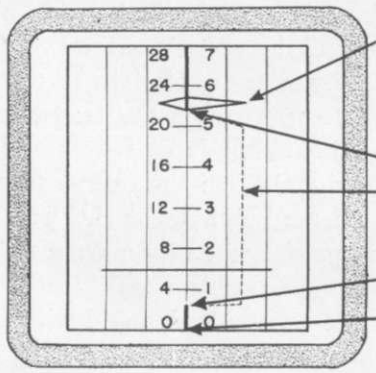
This equipment, with automatic computer for determining the release point, is designed to operate at altitudes of from 50 to 500 feet and relative velocities of aircraft and target from 50 to 400 knots. Means are provided for adjustment of the release point to enable dropping the first of a train of bombs so that the bombs will "straddle" the target. This same control may be used to correct the dropping point for variations in bomb trajectory due to wind resistance.



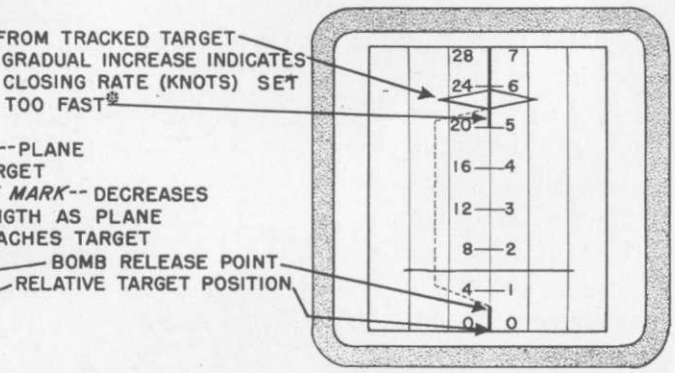
(A) SEARCHING CONDITION--WITHOUT AN/APA-16 ATTACHMENT OR WITH IT AND RANGE MARK KNOB LOCKED IN DEPRESSED POSITION



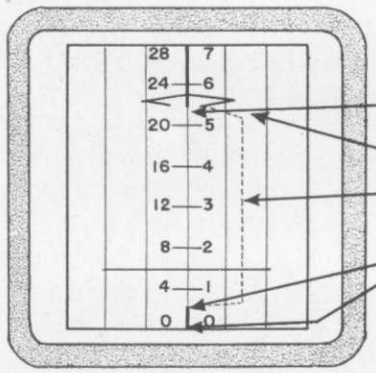
(B) TRACKING CONDITION--CONTROL UNIT PROPERLY ADJUSTED TARGET DEAD AHEAD



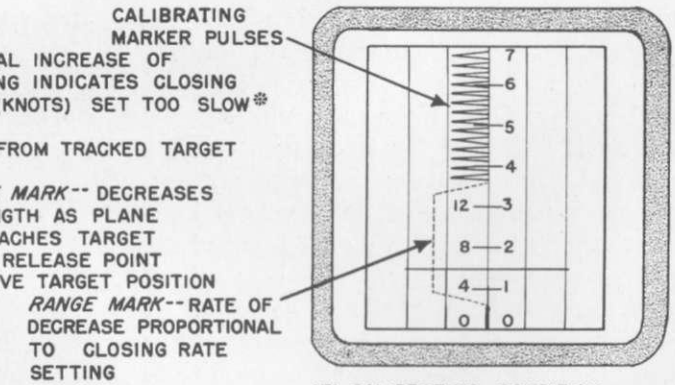
(C) TRACKING CONDITION--CONTROL UNIT PROPERLY ADJUSTED TARGET TO STARBOARD



(D) TRACKING CONDITION--CLOSING RATE (KNOTS) SET TOO FAST ON CONTROL UNIT



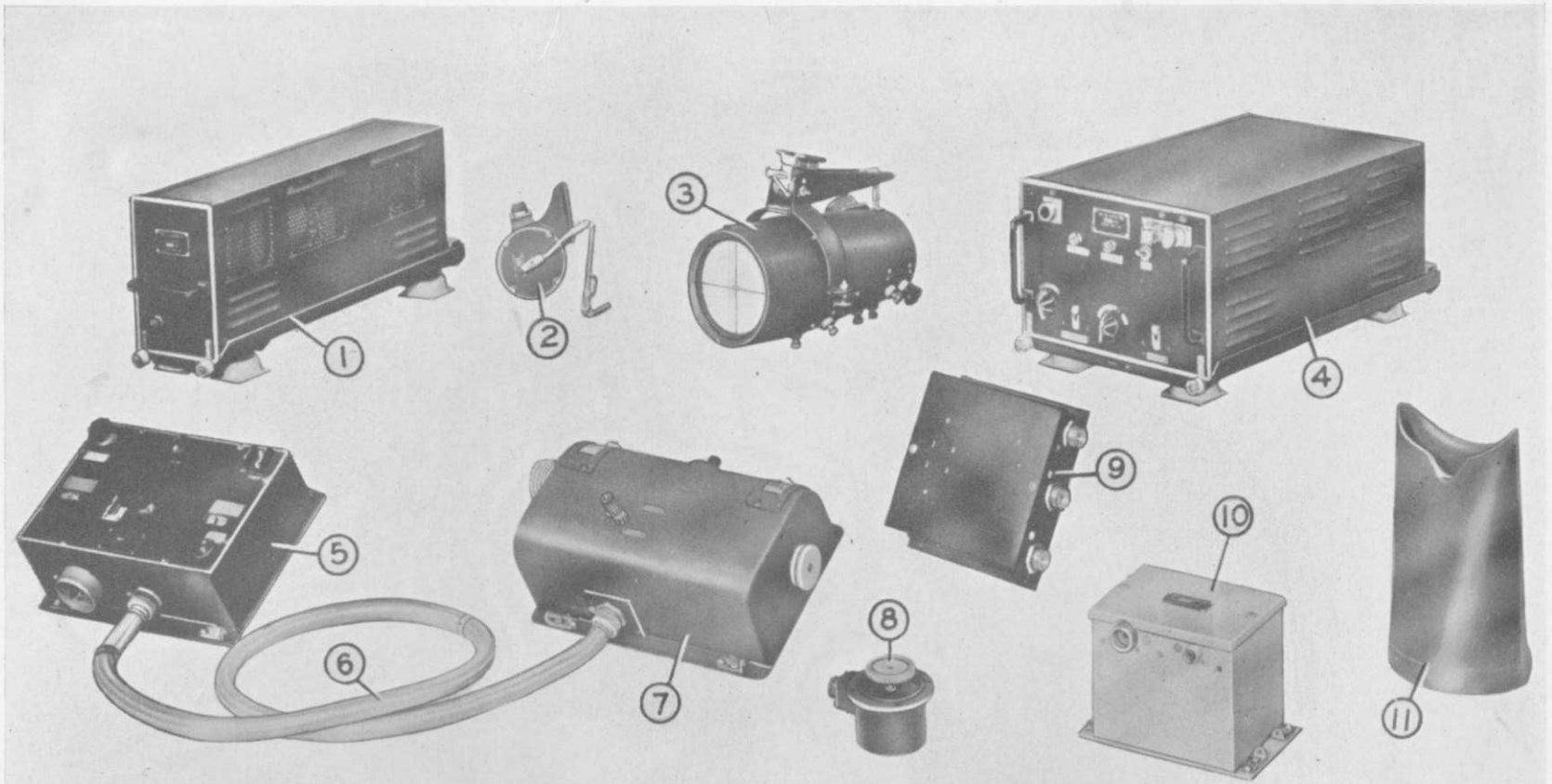
(E) TRACKING CONDITION--CLOSING RATE (KNOTS) SET TOO SLOW ON CONTROL UNIT



(F) CALIBRATING CONDITION--MARKER PULSES FROM T.S. 102/AP

* IF THESE CHARACTERISTICS ARE PRESENT BUT DO NOT INCREASE OR DECREASE, "CLOSING RATE" SETTING IS CORRECT AND "POSITION" SETTING IS INCORRECT.

Figure 2–80.—Target indications and range marker blanking on the ASB indicator screen.



1. Rectifier PP-2/APQ-5
2. Compensator CN-1/APQ-5
3. Indicator ID-3/APQ-5
4. Synchronizer SN-8/APQ-5B
5. Control Box C-82/APQ-5B
6. Interconnecting Cable
7. Tracking Unit C-83/APQ-5B
8. Azimuth Potentiometer
9. Junction Box J-10/APQ-5A
10. Capacitor Unit MX-12/APQ-5A
11. Indicator Hood

AN/APQ–5B

I. FUNCTION

AN/APQ–5B is a low- and high-altitude bombing attachment designed to operate in conjunction with certain airborne radar equipments for the purpose of automatically releasing a bomb (or train of bombs) at such a point that it will hit a desired target. (See NOTE, p. 84.)

II. DESCRIPTION

The main components of AN/APQ–5B are:

1. Synchronizer.
2. Control unit.
3. Tracking unit.
4. Indicator.
5. Compensator.
6. Rectifier, junction box and capacitor unit. (Also required as accessories are a bomb sight stabilizer and an adapter kit for connecting the AN/APQ–5B to the parent radar.)

III. MODE OF OPERATION

The basic operation of this equipment is as follows:

1. The associated radar equipment produces a train of extremely short but intense pulses of high-frequency energy and transmits these in a highly directive beam. Remote objects in the path of the beam reflect some of this energy, and a portion of it is intercepted by the antenna. These received echoes ultimately appear as a train of pulses recurring at the same rate as the outgoing train but delayed in time depending upon the distance separating the target from the aircraft. By observing this time delay, it is possible to determine the distance to the target, and by noting the heading of the beam when echoes are received, to ascertain the relative bearing of the object. This information usually is presented on the B- or PPI-scope of the radar.

2. AN/APQ–5B also operates from these video pulses, together with a reference trigger pulse marking the time of the outgoing signal. A separate B-type scope is furnished on which is impressed the target echo and a reference range marker which appears in the center of a one-mile sweep. This range marker and associated sweep can be moved toward zero range at a rate which corresponds to the relative velocity of the aircraft and target. This rate is adjusted during the bombing run so that the target coincides with the reference marker at all times. A release pulse or pip is also generated, which is adjustable in range to correspond to the proper release point of the bomb. This release point is a function of the relative velocity of the aircraft and target and the altitude of the aircraft. When the reference pulse or range marker which is coincident with the target echo arrives at the release point, the electrical addition of this pulse and the release point pulse energizes the elecrical bomb release mechanism and drops the bombs. An 18-mile alternative sweep for the scope is furnished and is employed at the beginning of the bombing run to prevent confusion in the case of multiple targets and to aid in the proper selection of a specific target.

3. The azimuth scale of the B-scope consists of three inscribed vertical cross hairs and the amplitude of the azimuth sweep covers an angle of approximately $\pm 60°$. Means are provided to enable the bombardier to set up the course of the bombing run so as to intersect the target regardless of drift conditions. The bombardier has only to maintain the target indication coincident with the central vertical cross hair of the B-type indicator by operation of the usual bomb sight turn controls. This operation controls the automatic pilot mechanism or the pilot direction indicator to alter the heading of the aircraft so that it travels along a collision course to the target.

4. AN/APQ–5B is designed to operate with an automatic computer for determining the release point at altitudes from 65 to 2,000 feet and relative velocities of aircraft and target from 100 to 400 miles per hour. Means are provided for adjustment of the release point to enable dropping a train of bombs centered on the target, and to correct the dropping point for variations in trajectory due to wind resistance. For higher altitudes up to a maximum of 50,000 feet, release distance is not determined automatically by the computer, but must be read by the bombardier from a chart provided for these conditions of altitude and velocity. The reading is set on the control dial manually.

5. For high-altitude bombing, AN/APQ–5B becomes a semisynchronous impact-predicting bombsight. A maximum of 70,000 feet slant release range is provided. Altitude information is set into the equipment by moving the release pip to a point coincident with the altitude ring. To this is added the B-factor. (The B-factor is the difference between slant release range and altitude and is affected very little by altitude changes from 10,000 to 50,000 feet.) This B-factor is presented in a tabular form and is selected by the operator for the conditions of altitude, velocity, and bomb type.

IV. PERFORMANCE CHARACTERISTICS

1. *General.* AN/APQ–5B will operate day or night under temperature conditions ranging from −40° to ÷50° C. (−40° to +122° F.) with relative humidities as high as 95 percent.

2. *Associated equipment.*—AN/APQ–5B is designed for use with aircraft search radars such as AN/APS–2, AN/APS–3, AN/APS–4, AN/APS–15, AN/APS–15A and AN/APS–15B types with a minimum of change in these installations. The attachment of the indicator equipment does not interfere with the normal functioning of the radars when properly installed.

3. *Search distance.*—This equipment may be used as a search indicator with an 18-statute-mile range to facilitate the location of a target at the beginning of the run.

4. *Bomb spread.*—Provision is made for releasing a train of bombs, centered on the target, with a normal spread of 830 feet between the first and last bombs of the train.

5. *Altitude and airspeed.*—AN/APQ–5B is designed to work between altitudes of 65 feet and 50,000 feet, and at airspeeds of 100 to 400 miles per hour. These limits are, however, dependent upon ground speed and altitude flown.

6. *Operational accuracy with X- and S-band radar sets.*—Tests made at an average air speed of 160 miles per hour indicate the radial error will be less than:

X-Band Radars

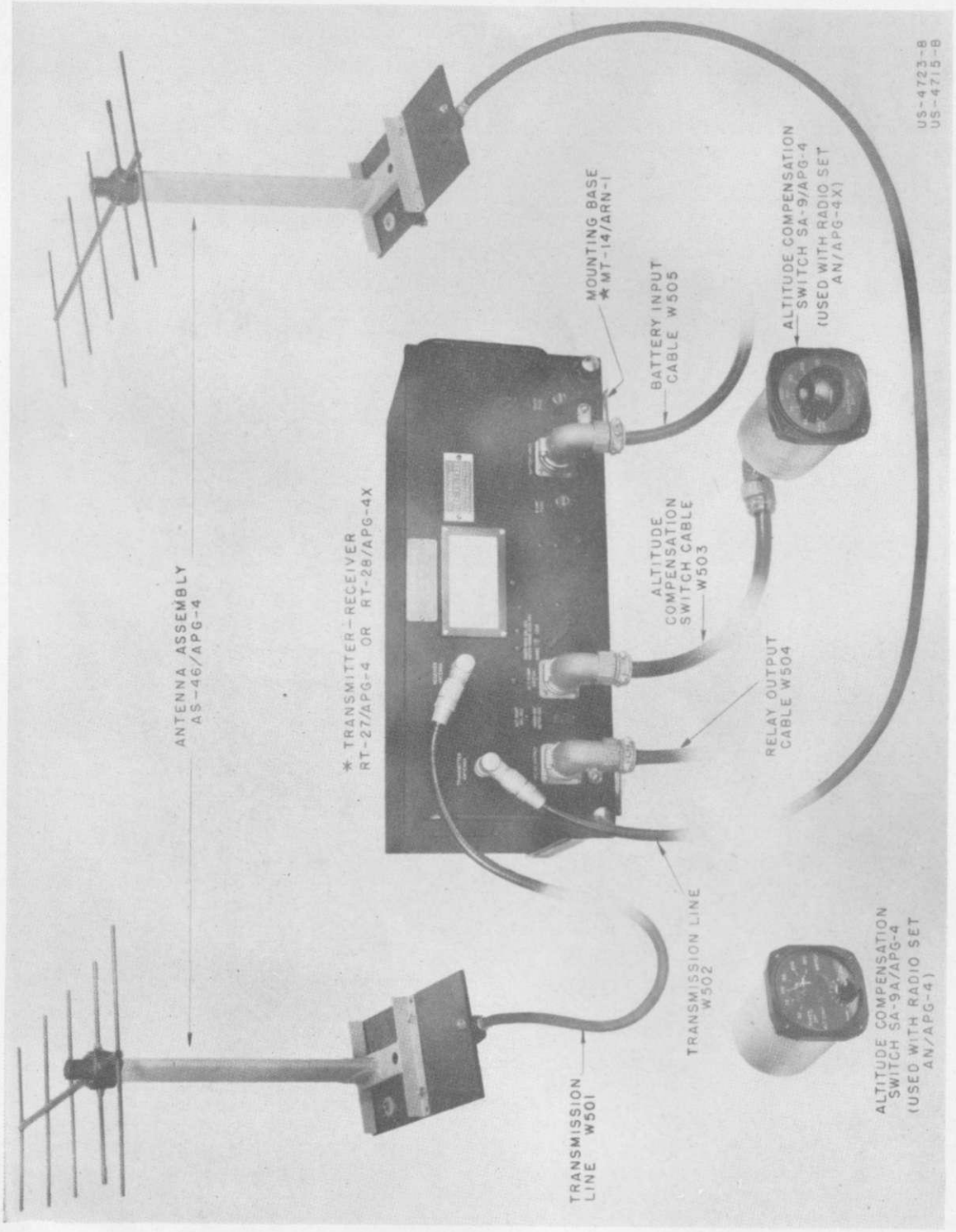
75 feet at altitude of 500 feet
100 feet at altitude of 1,000 feet
125 feet at altitude of 1,500 feet
140 feet at altitude of 2,000 feet

S-Band Radars

150 feet at altitude of 500 feet
175 feet at altitude of 1,000 feet
185 feet at altitude of 1,500 feet
240 feet at altitude of 2,000 feet

The greater part of this error will be in deflection rather than range. A train of three bombs usually insures a direct hit.

NOTE.—The AN/APA–5 is a radar bombing attachment which effects synchronous tracking and automatic bomb release on any target visible to the parent radar, replacing the AN/APQ–5B because of greater accuracy, altitude range and flexibility. This equipment operates with excellent accuracy at altitudes from zero to 35,000 feet and at closing speeds from zero to 400 miles per hour. Both range and azimuth tracking are provided. Accuracy is about 25 mils. It will operate with the AN/APS–2, AN/APS–3, AN/APS–15, and AN/APS–30 series radars. Modifications at an early date will provide for offset bombing and for rocket firing.


ANTENNA ASSEMBLY
AS-46/APG-4
* TRANSMITTER-RECEIVER
RT-27/APG-4 OR RT-28/APG-4X
MOUNTING BASE
* MT-14/ARN-1
BATTERY INPUT
CABLE W505
ALTITUDE COMPENSATION
SWITCH SA-9/APG-4
(USED WITH RADIO SET
AN/APG-4X)
US-4723-8
US-4715-8
ALTITUDE
COMPENSATION
SWITCH CABLE
W503
RELAY OUTPUT
CABLE W504
TRANSMISSION LINE
W502
TRANSMISSION
LINE W501
ALTITUDE COMPENSATION
SWITCH SA-9A/APG-4
(USED WITH RADIO SET
AN/APG-4)

AN/APG-4

AN/APG–4

I. FUNCTION

AN/APG–4 is an air-borne electronic low-altitude bomb release device designed to effect automatic release of a missile from an aircraft, directed toward an isolated or semiisolated marine surface vessel. It is complete in itself except for the employment of a radio altimeter (AYD, AN/ARN–1, AN/APN–1) which provides automatic compensation for altitude variation.

After a collision course has been established visually, or by means of a search radar (separately operated), AN/APG–4, within the operating limits of the equipment, evaluates closing rate and altitude to automatically release the bombs at the proper point.

II. DESCRIPTION

The AN/APG–4 consists of:

1. A frequency-modulated transmitter-receiver unit.
2. An altitude compensation switch with controlling relays.
3. Two Yagi antennas (similar to ASB equipment).

The antennas are mounted so as to direct a beamed lobe of radio energy forward and downward from the aircraft. One antenna is used for transmitting the frequency-modulated signals generated in the transmitter; the other antenna is used to receive the returning echo signal from surface targets.

III. MODE OF OPERATION

Figure 2–81 shows a functional block diagram of the AN/APG–4 equipment.

With the aid of the radio altimeter, the aircraft is flown at any height between the altitude range of 40 to 400 feet. In the transmitter, a frequency-modulated signal is generated and delivered not only to the transmitting antenna but also directly to the receiver. The transmitted signal is beamed by the transmitting antenna ahead to a target and the reflected signal is received on the receiving antenna, from which it is fed to the receiver.

The instantaneous difference between transmitted signal frequency and reflected signal frequency produces in the receiver a third or difference frequency which is a measure of the distance between the aircraft and the target, and the closing rate. This information is resolved in the receiver circuits into voltages proportional to distance and closing rate, with compensation for altitude variation, which, after evaluation by the AN/APG–4, actuate relays at the proper time to operate the bomb release mechanism.

The factors of speed, altitude, and distance are thus automatically obtained by the equipment and evaluated to determine the point at which automatic bomb release takes place. Azimuth information must be obtained by pilot or operator either visually or through the use of air-borne radar equipment.

IV. PERFORMANCE CHARACTERISTICS

1. *Operating limits.*—AN/APG–4 is effective over a range of aircraft speeds of 100 to 300 knots and at altitudes of from 40 to 400 feet.

2. *Range lead adjustment.*—Provision is

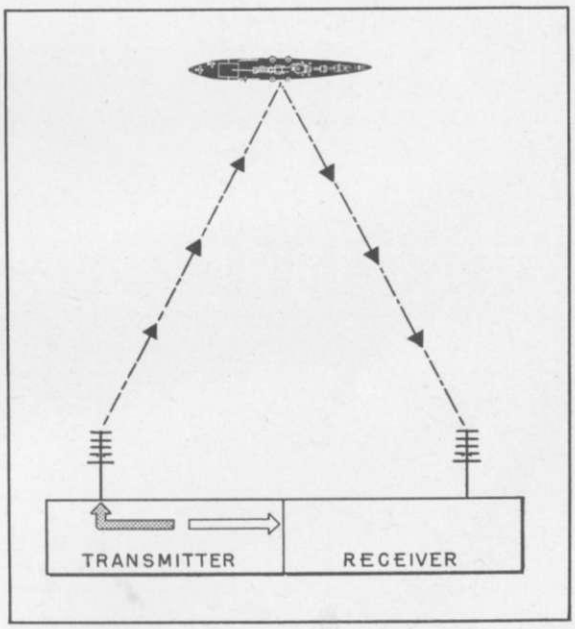


Figure 2–81.—In the APG–4 equipment, frequency-modulated signals are directed toward a target by the directional transmitting antenna. A small portion of the frequency-modulated signal is also fed directly to the receiver. Since a measurable period of time elapses from the time the signal (of a given frequency) was transmitted to the time it is received, the difference in frequency between the returned signal and the new frequency-modulated signal then being generated in the transmitter is resolved into terms of distance.

made in the equipment for releasing a bomb so that its point of impact may be anywhere from zero to 100 feet ahead of the selected target (skip-bombing application).

3. *Computation time.*—Because the automatic computation of bomb release time requires only four-tenths of a second, a pilot may engage in extreme evasive action up to a point immediately prior to bomb release.

5. *Target isolation.*—The equipment tracks and releases on the nearest object in view; therefore, it is essential that the target be isolated from objects by a minimum of approximately 150 yards.

NOTE.—The AN/APG–4 will be superseded by the AN/APG–17 and AN/APG–17–17A. The AN/APG–17A is a low-altitude level-flight frequency-modulated automatic bomb release system using either visual or radar sighting and permitting evasive maneuvers up to point of release. Range of altitude operation is from 40 to 400 feet and the equipment obtains its altitude information from the AN/APN–1 radio altimeter. It requires no operator other than the pilot. Two faired-in parabolic antennas are required. This equipment will supersede the AN/APG–4 due to better aerodynamic characteristics and greater power. The AN/APG–17A will provide for operation up to 800 feet and will be suitable for rocket release. The weight is slightly less than the AN/APG–4 (5 to 10 pounds estimated).

AN/APG–5

I. FUNCTION

A. Primary purpose. AN/APG–5 is a lightweight air-borne fire-control radar equipment. It is an automatic ranging equipment which supplies target information to a lead computing sight, as used in the upper and lower gun turrets of aircraft.

II. DESCRIPTION

A. Main components. AN/APG–5 consists of the following:

1. A transmitter-receiver unit.
2. A directional antenna.
3. A range unit.
4. Servo amplifier and servo-geared motor unit.

B. Mode of operation. The transmitter generates pulses of radio-frequency energy which are fed to an antenna having highly directional qualities. The antenna, mounted on the gun turret and rotatable with it, directs the radio-frequency pulses toward a selected target in a 28° beam.

Echo pulses from the target return to the same antenna and are fed to the receiver and range unit. The range unit performs the function of measuring the time intervals between transmitted pulses and received echoes, continuously maintaining a voltage output proportional to the time interval, and therefore to range.

The servo amplifier and its associated servo-geared motor unit converts this voltage output to a shaft rotation proportional to range, which may, in turn, be fed into a lead computing sight.

The AN/APG–5 is entirely automatic in operation and requires no separate operator. The gunner operates the necessary controls. Using his optical sight, the gunner operates his turret and his guns in such a manner as to visually train his guns on the target. This simultaneously aims the radar antenna at the target. AN/APG–5 then automatically tracks the target in range and will indicate to the gunner that it is feeding range information into his sight. This indication is in the form of a target indicator light which is placed on the sight so that it may be readily observed by the gunner without the need for shifting his view from the target. The gunner then merely keeps his guns trained on the target and fires when at the proper range.

In the event there is more than one target present, the gunner may select a closer or a more distant target by pressing the IN or OUT switch of the target selector, which is mounted on the handle bar control. He can tell when he is on the proper target by noting the relative range as indicated by the reticule separation on the optical sight.

In the event of radar failure, the target indicator will not operate. When this occurs, the gunner can immediately regain manual control. He operates his sight by using the target selector to drive the servo-geared motor unit, which, in turn, drives the range mechanism of the sight. In doing this, he uses the sight as he would if there were no radar equipment installed.

C. Performance factors. The AN/APG–5 system will operate in ambients from minus 55° C. to plus 50° C.

The system is capable of automatically tracking aircraft reliably to a minimum distance of 200 yards.

The over-all system error, on the 1,800-yard scale, is less than ±50 yards.

The system is designed to operate between the limits of 6,000 to 40,000 feet altitude.

PART THREE

RADAR BEACONS

RADAR BEACONS—PRINCIPLES OF OPERATION

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PART THREE

RADAR BEACONS

RADAR BEACONS (RACONS)—PRINCIPLES OF OPERATION

I. PULSE AND ECHO VERSUS DIRECT TRANSMISSION

A radar transmitter sends out pulses of radio energy in a beamed path. When an object is in the path of the beam, it reflects back a small portion of the transmitted energy to the source, where it is displayed visually on a cathode-ray tube screen to indicate the presence, bearing, and range of the object. This main function of a radar employs the pulse-and-echo cycle of operation.

However, if the beamed pulses from the radar strike the antenna of a radar beacon installation, the radar beacon, normally dormant, is triggered into action and in turn transmits powerful omnidirectional radio waves. (See fig. 3–1.)

Figure 3–1.—The outward-going pulses from the aircraft's radar strike the beacon transmitter, which is triggered into operation and sends out a powerful coded signal in all directions.

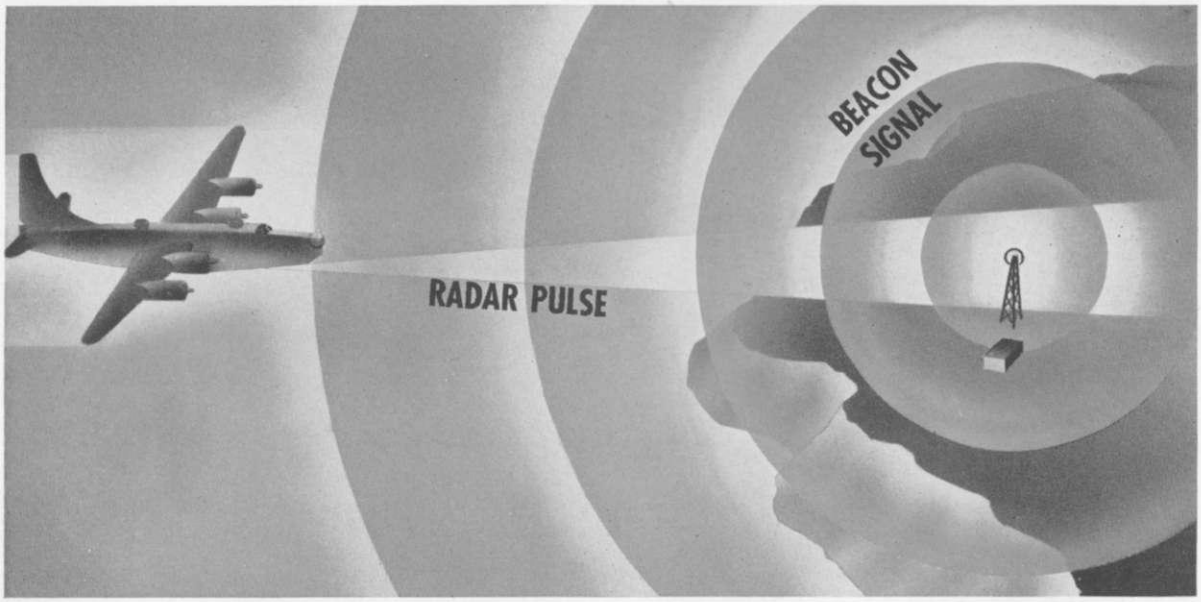
II. CHARACTERISTICS

Beacon transmissions have three predominant characteristics which contribute to the function of the beacon as an aid to navigation:

1. The transmission occurs at a frequency slightly higher than that of the initiating radar pulse. Therefore, these transmissions are not displayed visually on the radar scope screen in the aircraft until the radar receiver is retuned away from the radar frequency to accept the higher beacon frequency. Retuning the radar receiver not only allows the beacon signal to be observed visually but also rejects radar echoes which might otherwise cause a confused screen pattern.

2. Beacon signals as transmitted are coded so as to furnish the identity of the beacon station to the interrogating aircraft.

3. The transmissions from the beacon station are not beamed in any one given direction, but, rather, are radiated in all directions. In the interrogating aircraft, the relative bearing of the beacon is indicated by the azimuth position



of the antenna and the corresponding location in azimuth of the signal indication on the scope screen (fig. 3–2).

III. RANGE/ALTITUDE

The range at which radar beacon signals can be received is greater than that obtained in normal radar operation. This is because in radar operation the strength of the indication, all other factors being equal, is dependent upon the strength of the reflected echo, whereas in beacon operation the received signal displayed on the scope is produced by a strong, directly transmitted signal from the beacon station.

Range is also dependent upon the altitude of the interrogating aircraft. If the aircraft is flying low, the path of the radar beam to the horizon is short. A beacon transmitter beyond the horizon at that altitude may not be triggered into operation. Increasing the altitude increases the distance to the horizon and brings the radar beacon station, previously hidden by the horizon, into the path of the radar beam.

IV. CODING

Transmissions from radar beacons operating in the P–L frequency bands (YJ) are gap coded. See L-scan, figure 3–3. A motor-driven coding disc having raised cams operates a micro-switch to key the transmitter circuit for long or short periods of time, producing two-letter Morse Code signals.

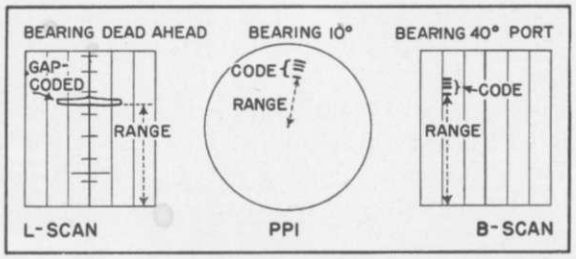
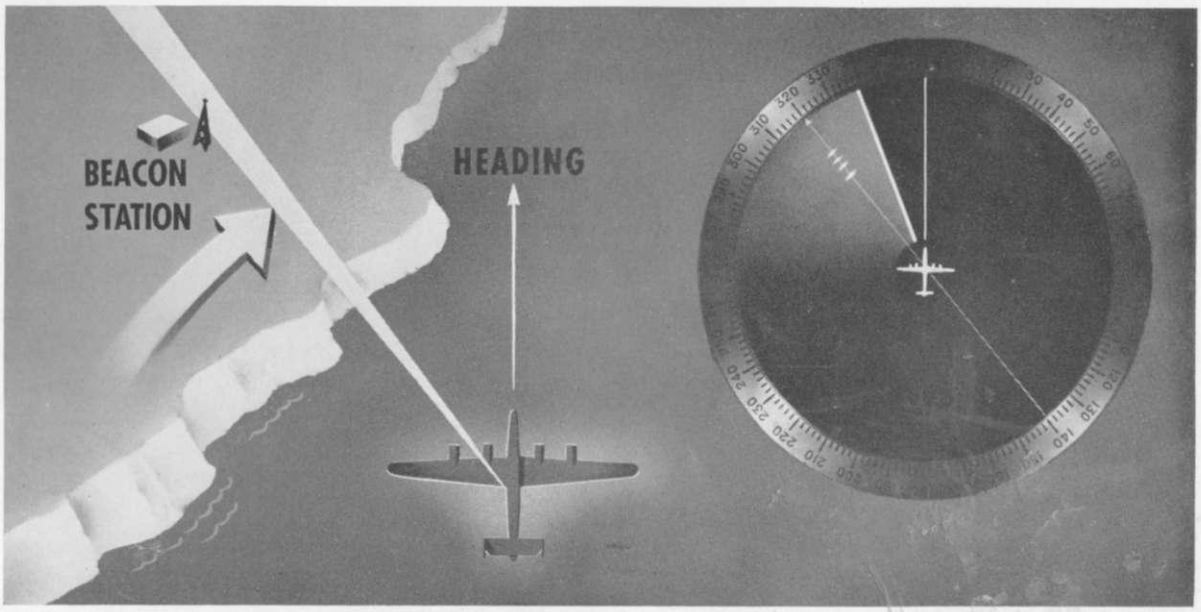


Figure 3–3.—Depending upon the type of air-borne radar equipment used and the radar beacon with which it is used, beacon signals are either displayed as gap-coded indications or range-coded indications. For instance, on air-borne radar equipment employing the L-scan the beacon signal blinks on and off in accordance with 2-letter signals of the International Morse Code. On equipments employing the PPI or B-scan radar signals appear range coded; that is, a series of vertically spaced light spots appear on the scope screen, their separation and number denoting the specific coding employed.

The speed of rotation of the code disk is such that the complete series of signals comprising a two-letter code is transmitted within a 30-second period.

At the receiving end (radar interrogator), these signals, displayed on the scope, appear as recurring blips on the trace, the duration of the blips signifying the "dots and dashes" of the two-letter code.

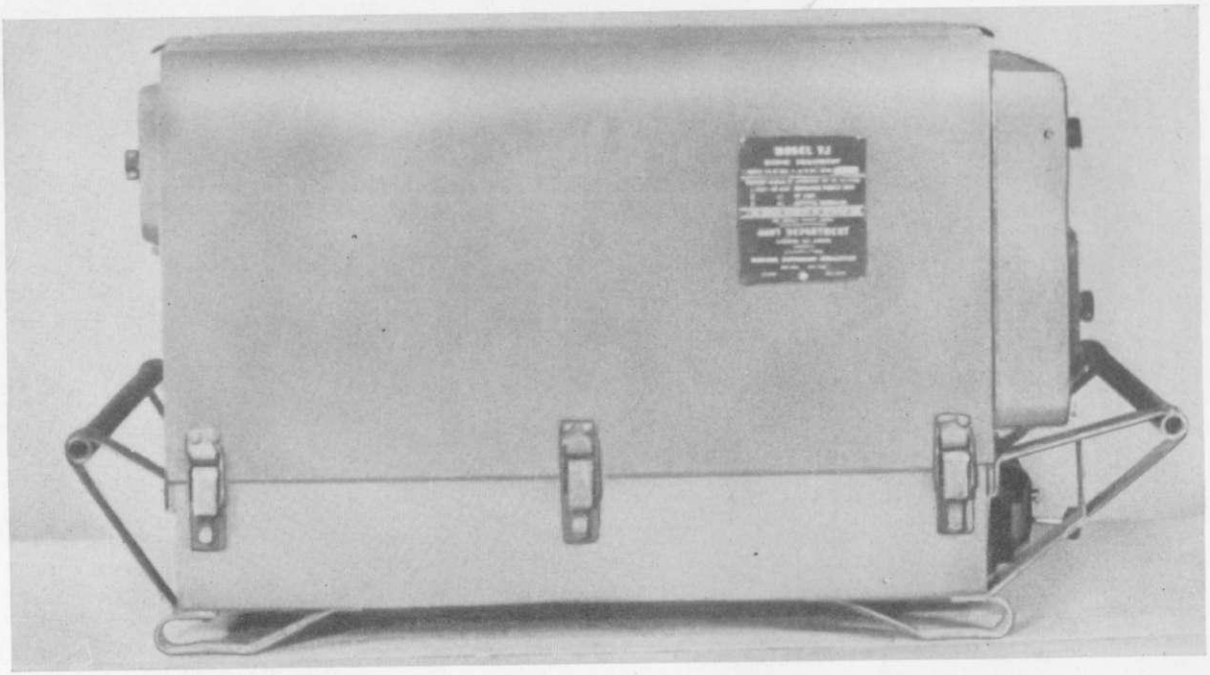
Figure 3–2.—Since the trace on the PPI rotates in azimuth in step with the antenna, the azimuth position of the coded signal on the PPI denotes bearing of the beacon station.

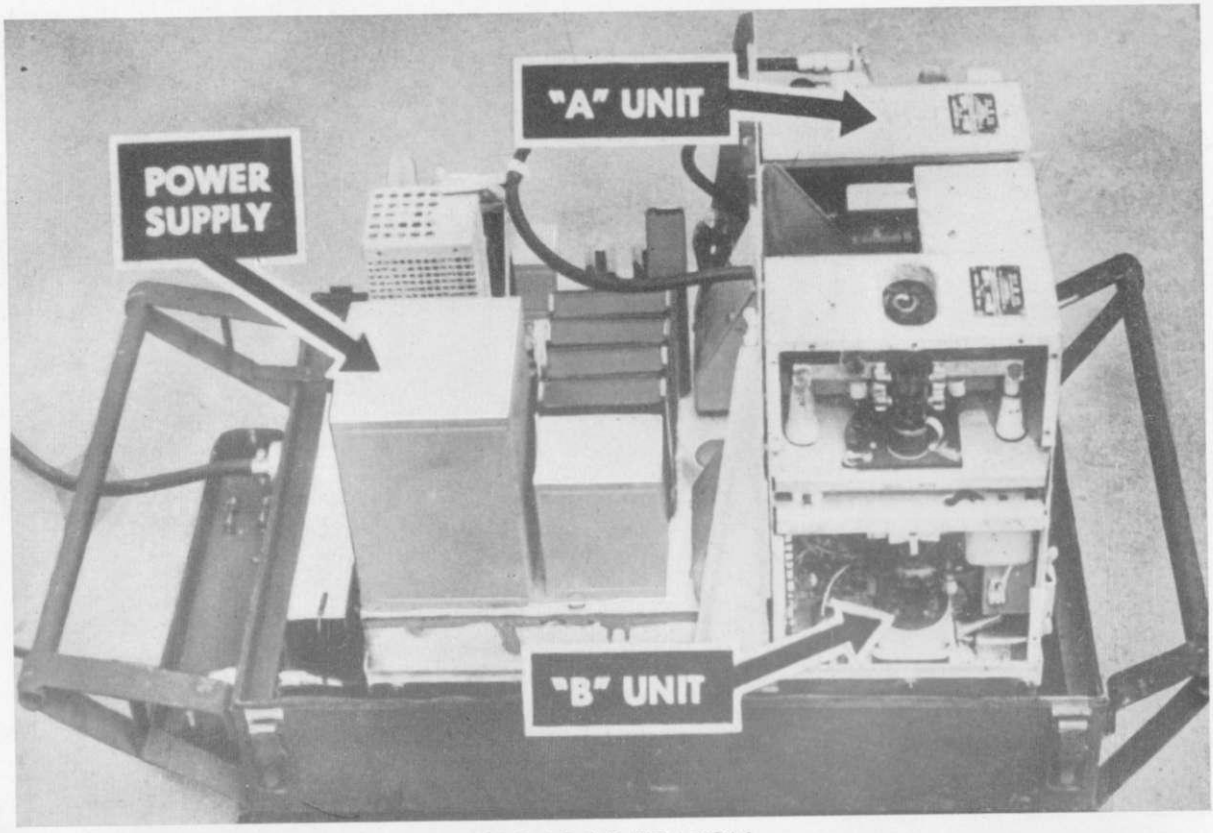


Range to the radar beacon is indicated by the position of the blip along the trace, up from the bottom of the scale. Bearing of the radar beacon with respect to the aircraft is indicated by the lateral displacement of the blip on the trace. When the beacon is dead ahead the lengths of the blip on either side of the trace would be equal.

Transmissions from radar beacons operating in the S and X frequency bands (AN/CPN–3 and AN/CPN–6, respectively) are range coded; i. e., the coded response consists of a number of time-spaced signals (six or less) occurring so rapidly (15 to 35 microseconds) that, at the radar receiving location, they appear on the PPI or B-scan screen of the indicator as a series of spots of light arranged as to number and spacing to indicate the radar beacon's identity. See PPI and B-scan, figure 3–3.

Range to the radar beacon is indicated by the position on the trace of the lowest signal in the coded series. Bearing is indicated by the azimuth position of the entire coded series of spots.





YJ RADAR BEACON

YJ RADAR BEACON

I. FUNCTION

The YJ radar beacon, furnishing coded signals to radars operating in the L and P frequency bands, is designed to act as an aid to homing and as a means of locating an aircraft's position with respect to the radar beacon.

II. DESCRIPTION

A. MAIN COMPONENTS. YJ radar beacon equipments consist of:

1. Antenna assembly.
2. Beacon transmitter-receiver and power supply unit.

1. The antenna assembly comprises two separate radiator units (one for operation on the L band of frequencies, the other for operation in the P band of frequencies), a supporting mast, and a coaxial feeder cable for connecting the antenna to the transmitter-receiver unit.

2. The transmitter-receiver unit consists of two separate transpondors, designated "A" and "B," for operation in the P and L frequency bands, respectively.

The power supply unit operates from a 110-volt, 800-cycle a. c. source and furnishes the required operating voltages to the "A" and "B" transpondor units.

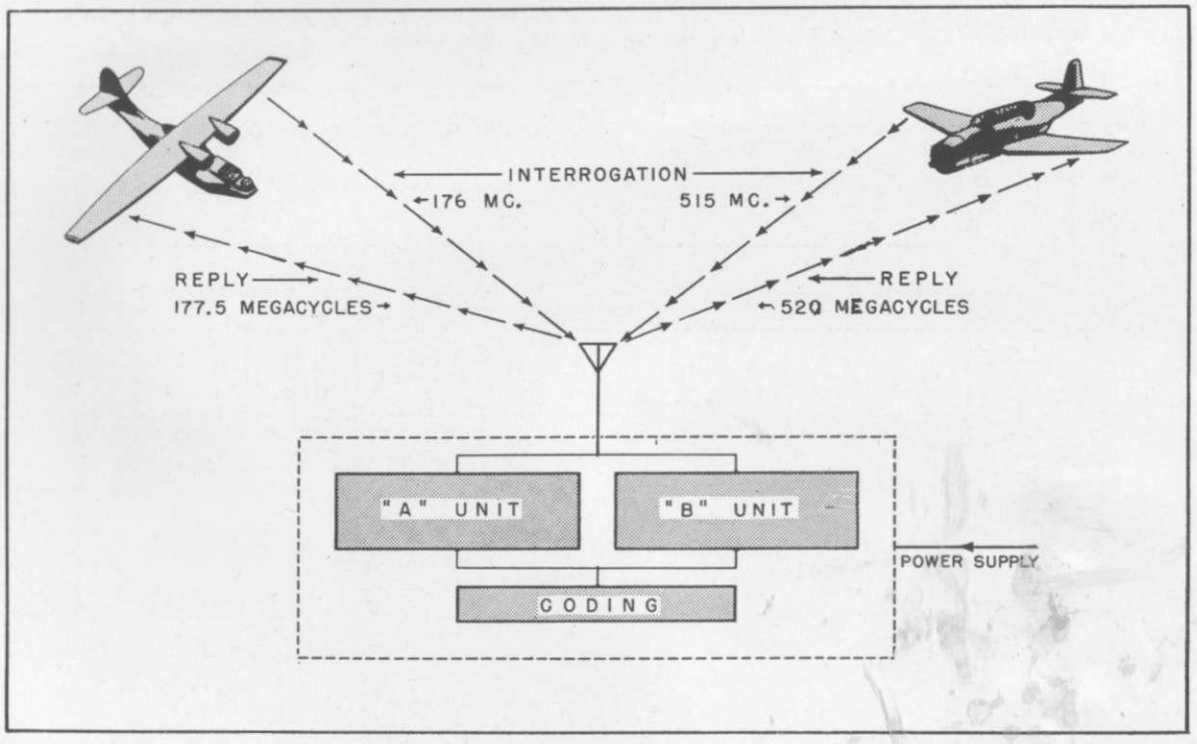
B. OPERATION. 1. YJ is a transpondor (transmitter-receiver) type of electronic equipment, ship-based or land-based, which, when triggered into operation by the reception of beamed radar pulses from ship or aircraft, transmits gap-coded replies omnidirectionally.

At the radar-interrogating ship or aircraft, these coded replies are received by the radar and displayed on the radar scope to denote identity, range, and bearing of the radar beacon.

The receiver circuits of the YJ transpondor are tuned to accept pulses from radars operating at 176 megacycles and 515 megacycles. The transpondor responds by alternately transmitting signals of 177.5 and 520 megacycles on a time-sharing basis.

NOTE.—Specific mention of operating frequencies is made here to facilitate complete understanding of the operation of the equipment in question. With reference

Figure 3–4.—The YJ radar beacon contains two separate transpondors—an "A" unit and a "B" unit—which furnishes replies to radars interrogating on 176 and 515 megacycles, respectively. The coded reply enables the beacon to be identified.



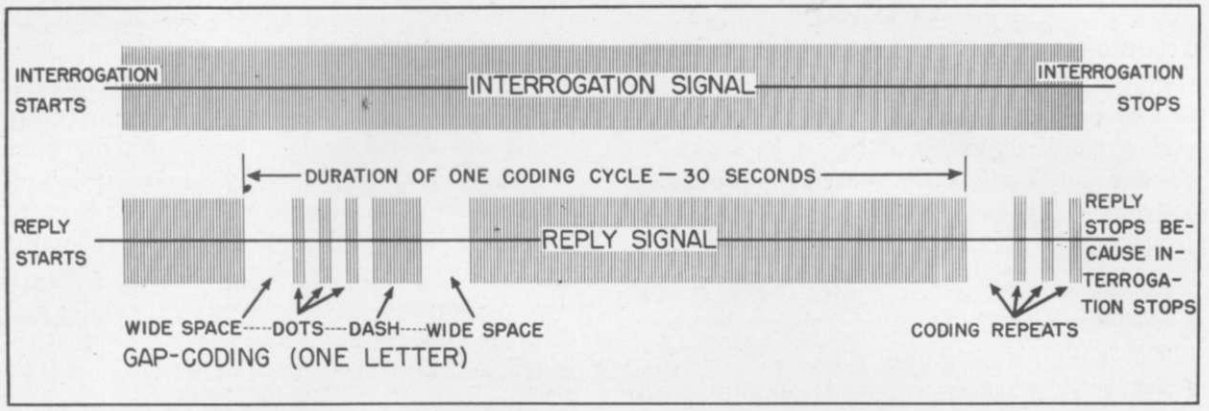


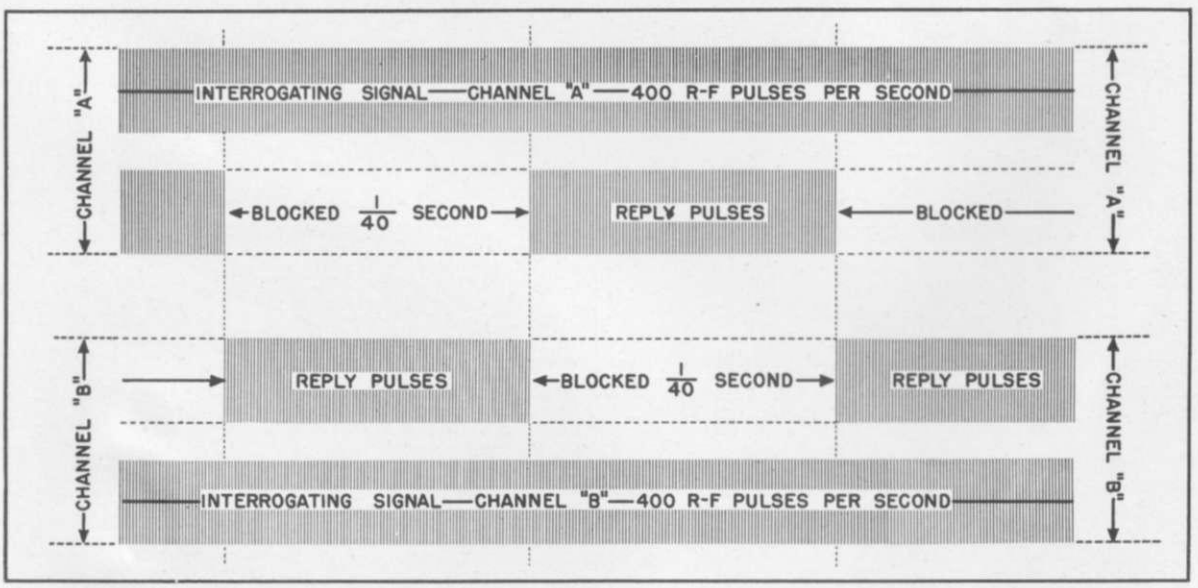
Figure 3–5.—As long as the equipment continues to receive an interrogating signal on either channel it transmits a coded reply on the same channel. The code, which can consist of two letters, or only one, as shown here, repeats every 30 seconds.

to correspondence or conversation regarding specific operating frequencies, readers of this manual are cautioned to observe security regulations as outlined in Part I, pages 5 and 6.

On board the radar-interrogating ship or aircraft, the radar receiver must purposely be tuned away from the regular pulse-and-echo frequency to the radar beacon frequency in order to receive the beacon replies. As a result, the radar scope does not present radar echo displays but shows only the beacon signal in the form of a series of blips of dot and dash duration whose coded sequence denotes the beacon's identity.

2. *P and L band triggering.*—P-band radar pulses which are beamed directionally to strike the P-band antenna are fed to the "A" transpondor to trigger it into operation as a transmitter. Its reply, interrupted by a coding disk, is transmitted omnidirectionally by the same antenna receiving the radar pulses.

Figure 3–6.—To prevent one transmitter from firing the other, one is blocked for about one-fortieth of a second during which the other transmitter can reply as interrogated. Then the second one is blocked while the first one is allowed to answer on interrogation. The blocking period is, however, so short that the reply appears continuous to an observer at the cooperating radar.



In a like manner, radar pulses from radars operating in the L-band of frequencies are picked up by the L-band antenna and fed to the "B" transpondor to trigger it into transmitting operation. See figure 3–4.

As long as the equipment continues to receive an interrogating signal on either channel, it transmits a coded reply on the same channel. See figure 3–5.

3. *Time sharing.*—Reception of both P- and L-band radar pulses can be simultaneous. Transmission of coded replies to simultaneous reception is performed by the equipment on a time-sharing basis. See figure 3–6.

4. *Selective response.*—Adjustments to the operating controls of YJ permit either the "A" and "B" transpondor to be selected for full-time response. During the period the equipment is so adjusted, only the selected transpondor operates.

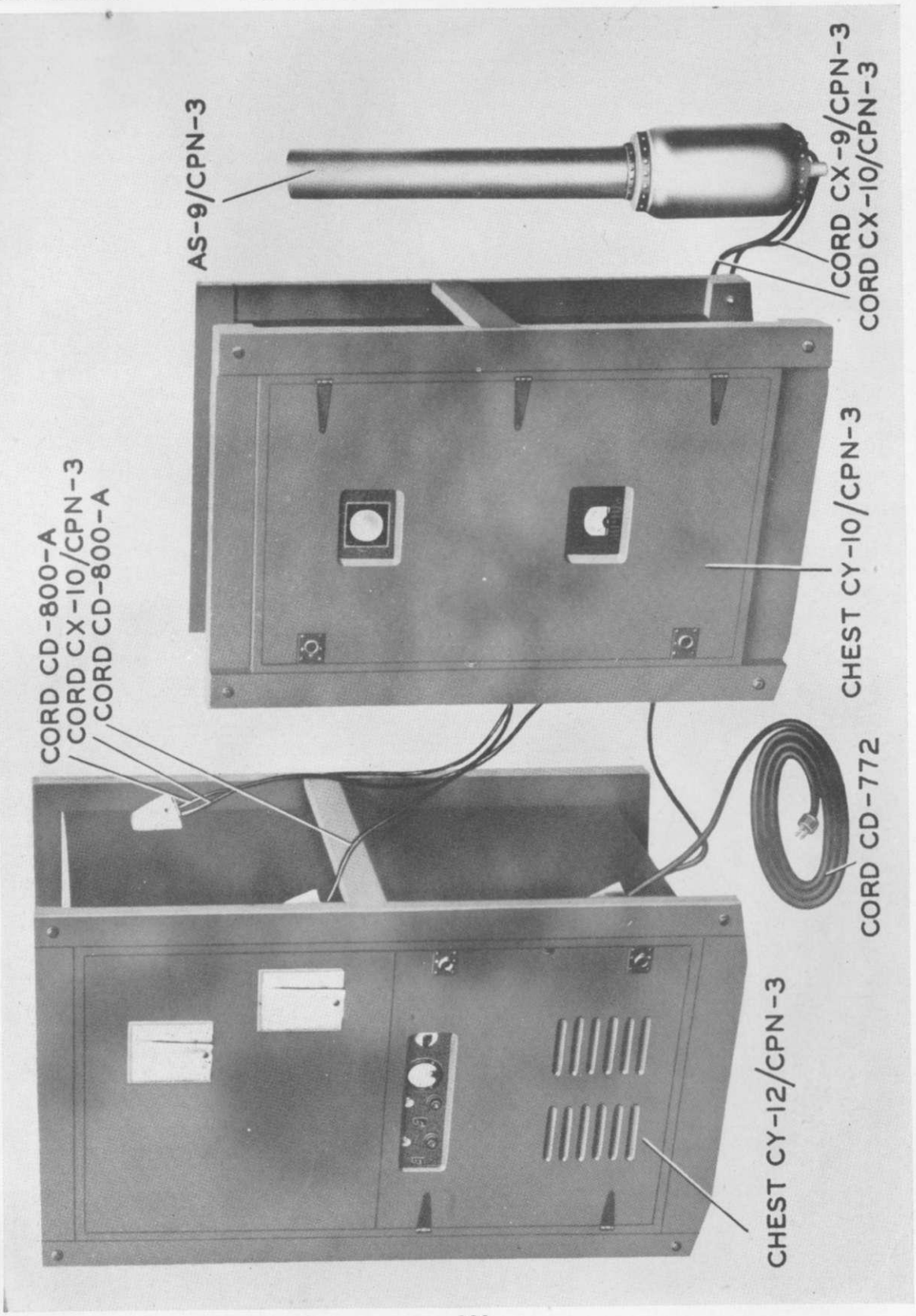
5. *Coding.*—Coded replies to radar interrogations are furnished through the operation of a motor-driven code disk whose arrangement of interruptor cams key the transmitted replies in one- or two-letter Morse Code.

NOTE.—Shipboard YJ's will not normally have an A-band unit operating in the P-band of frequencies. It will utilize only the B-band unit operating in the L-band of frequencies for use with air-borne radar equipments installed in carrier-based aircraft.

III. TACTICAL EMPLOYMENT

For the tactical employment of YJ as a beacon homing system for radar-equipped (ASB) aircraft, see p. 35.

The YJ radar beacon, when triggered into operation by radars operating on either the P- or L-band of frequencies will transmit radio signals which can be received by the enemy to provide him with directional information as the bearing of the YJ location. Tactical commanders, therefore, are faced with the problem of determining whether aircraft employed in a strike should be permitted to return to base by YJ homing or whether it is more important from the standpoint of tactical surprise to maintain all radar silence.


AS-9/CPN-3
CORD CX-9/CPN-3
CORD CX-10/CPN-3
CHEST CY-10/CPN-3
CORD CD-800-A
CORD CX-10/CPN-3
CORD CD-800-A
CORD CD-772
CHEST CY-12/CPN-3
AN/CPN-3

AN/CPN–3 (YK) AND AN/CPN–6 (YM)

I. FUNCTION

A. AN/CPN–3 and AN/CPN–6 radar beacons, furnishing signals to radars operating in the S and X bands, respectively, are designed to act as aids to homing and as a means of locating an aircraft's position with respect to the radar beacon location.

II. DESCRIPTION

A. MAIN COMPONENTS. Radar beacons AN/CPN–3 and AN/CPN–6 consist of:

1. Antenna assembly.
2. Beacon transmitter-receiver and power supply unit.

Fundamentally, these radar beacons are similar to each other. Their difference are chiefly in circuit design and in the frequencies on which they receive and transmit.

These beacons may be ship-borne or land-based.

B. MODE OF OPERATION. 1. *Beacon triggering.*—One characteristic which makes these beacons different from the YJ type of radar beacon (L- and P-band operation) is that they do not respond to all radar pulses received within their respective operating frequency bands. While the beacon station can receive pulses from *all* radars operating within the band of frequencies accepted by the beacon (provided, of course, that the radar pulses are directed toward the beacon station), the use of a discriminator circuit in the beacon receiver allows the beacon to respond only to those radar pulses which are of 2 microseconds duration.

The normal pulse length of air-borne radars employed for search varies from 0.5 to 1 microsecond. These pulse lengths will not trigger the beacon into operation. When an air-borne radar is switched to beacon operation, its pulse length is automatically increased to 2 microseconds duration. These pulses, when received by the beacon will be accepted by the discriminator and will trigger the beacon into operation.

It follows, then, that even though a beacon station is within the field of the beam from an air-borne radar, the beacon will not make known its presence by replying to radar pulses until the air-borne radar has been set to transmit the 2-microsecond beacon triggering pulses.

2. *S-Band.*—AN/CPN–3 will receive interrogations from S-band air-borne radars whose individual operating frequencies may be anywhere within a 66-megacycle band, from 3267 megacycles to 3333 megacycles. The beacon transmitter, however, will respond only on 3256 megacycles, and the receiver portion of the air-borne S-band radar equipments must be tuned to this frequency in order to receive the beacon response.

3. *X-band.*—AN/CPN–6 will receive interrogations from air-borne X-band radars whose individual operating frequencies may be anywhere within a 110-megacycle band, from 9320 megacycles to 9430 megacycles. The beacon transmitter, however, will respond only on 9310 megacycles and the receiver portion of air-borne X-band radar equipments must be tuned to this frequency in order to receive the beacon response.

NOTE.—Specific mention of operating frequencies is made here to facilitate complete understanding of the operation of the equipment in question. With reference to correspondence or conversation regarding specific operating frequencies, readers of this manual are cautioned to observe security regulations as outlined on pages 5 and 6.

4. *Coding.*—The coded responses of both the AN/CPN–3 and AN/CPN–6 appear on the radar screen of the interrogating aircraft as a vertical series of horizontal dashes, correct in azimuth and range. The number and spacing of the dashes furnish the radar beacon's identity.

5. *Range and bearing.*—Range is indicated by the placement of the coded response along the time trace as viewed on the radar indicator. In the PPI display, range is measured from the bottom of the lowest dash to the center of the screen. In the B-scan display, range is measured from the bottom of the lowest dash to the bottom of the rectangular screen.

Bearing of the radar beacon station is indicated by the azimuth position of an imaginary line drawn through the center of the coded signals.

III. TACTICAL EMPLOYMENT

The air-borne radar equipments which are served by the AN/CPN–3 (S-band) and AN/CPN–6 (X-band) are as follows:

S-band	*X-band*
ASG–AN/APS–2 Series, page 52.	AN/APS–15, page 41.
AN/APS–2F, page 52.	AN/APS–15A and '–15B, page 49.
	AN/APS–3, page 55.
	AN/APS–4, page 61.
	AN/APS–6A, page 67.

For detailed descriptions of the uses of these equipments for beacon bombing refer to the pages listed above.

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RECOGNITION—THEORY AND PRINCIPLES

I. GENERAL

Recognition is the process of determining the friendly or enemy character of another.

Identification is that process of indicating your friendly character.

IFF (*I*-dentification, *F*-riend or *F*-oe) is an electronic system installed in ships, aircraft and shore facilities to recognize friendly contacts made by radar.

All naval aircraft (excepting trainers) and commercial aircraft under contract to the Navy for transport operations are equipped with electronic devices which automatically reply to challenges from friendly shore-based, shipboard or air-borne electronic interrogators.

II. TYPES

Basically, IFF equipment may be divided into two broad classifications:

1. *Transpondors*—air-borne electronic equipments which only respond to challenges, to establish the friendly character of the challenged aircraft.

2. *Transpondor-interrogator-responsors*—air-borne equipments which not only respond to challenges but, in addition, can be used to interrogate targets to determine their identity, displaying the response, if any, on a scope screen.

III. MARK III SYSTEM

In the Mark III system (currently in use), when a detected radar target is to be interrogated, land-based or shipboard equipment transmits challenging pulses.

In the challenged target, such as an aircraft, the reception of these challenging pulses will trigger the transpondor into operation, which then transmits a coded reply to establish its identity for as long as it is challenged. At the challenging station, both the radar echoes and the IFF signals from the target are displayed.

In addition to responding to challenges to establish their own identity, air-borne equipments AN/APX–2 or AN/APX–8 can initiate challenges to interrogate and identify targets detected by their associated radars.

IV. TARGET ECHO AND IFF DISPLAY

Pulses from an aircraft's interrogator-responsor are transmitted at the same time as its radar pulses. The radar pulses are beamed directionally toward the target, which returns weak echo pulses. This occurs at the radar pulse-and-echo frequency.

At a much lower frequency, the interrogator-responsor transmits its pulses omnidirectionally (except AN/APX–8, which has a directional antenna system). At the target, reception of these challenging pulses will trigger the target's transpondor into action (if it is friendly), causing it to transmit, in turn, powerful omnidirectional pulses. See figures 4–1 and 4–2.

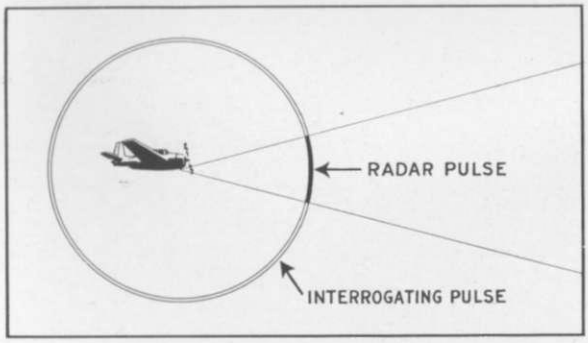

Figure 4–1.—The interrogator part of the I–R unit, when put into operation, sends out challenging pulses along with the radar pulses.

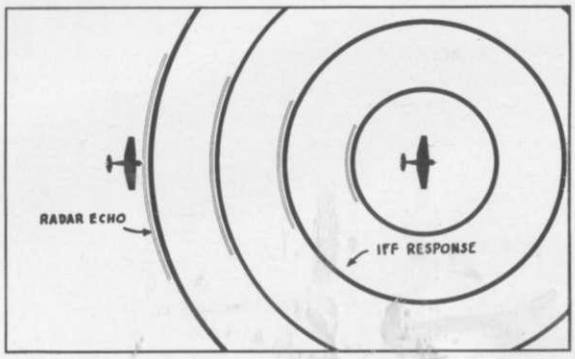

Figure 4–2.—Radar pulses return as target echoes, but the I–R challenging pulses trigger off the target's transpondor (if it has one). Its transponder then sends back a coded reply.

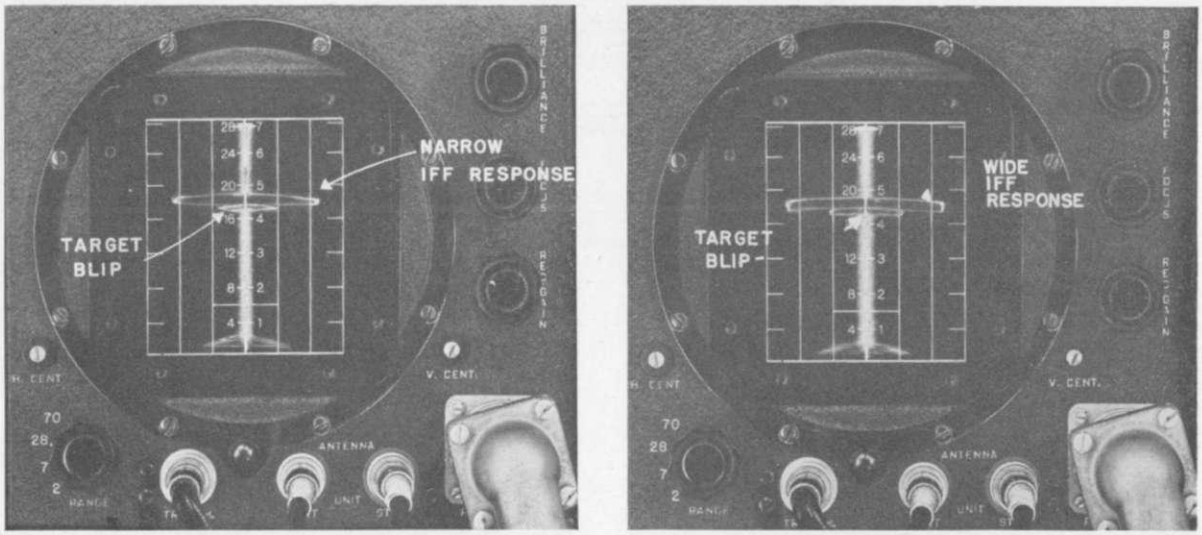

Figure 4–3.—Above is shown the IFF response as it appears on the L-type (ASB) scope. A coded series of wide or narrow blips appear just above the target blip.

Back in the challenging aircraft, the IFF equipment, which is tuned not to the radar frequency but only to the I-R (interrogator-responsor) frequency receives the omnidirectional signals.

In operation, the tuning mechanism is swept automatically through a wide band of frequencies about once every 3 seconds. Therefore, once every 3 seconds at some particular point during the sweep the responsor will be tuned to accept the frequency of the signal returning from the challenged transpondor. The signal output of the IFF receiver in the challenging aircraft is fed directly to the radar indicator where it is displayed on the scope as a characteristic IFF signal, together with the radar echo.

Since IFF reception is nondirectional (excepting with AN/APX–8), the IFF signal is displayed on the scope correctly with respect only to the target's range—not its bearing. See figures 4–3 to 4–6, inclusive.

Figure 4–6.—Here's the IFF display on the APS–4 air-borne radar scope. When land masses or other large targets interfere with just beyond the target blip. It is correct with respect to range only, not azimuth.

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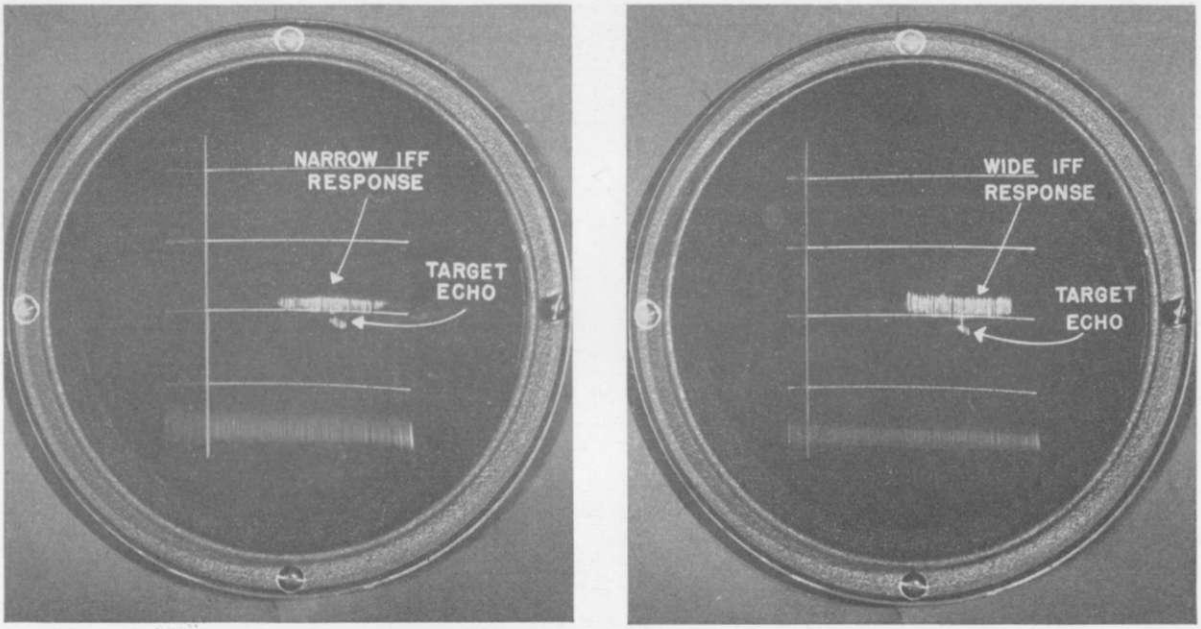


Figure 4–5.—IFF responses on the B-type appear as narrow or wide horizontal images located just above the target image.

V. CODING

Depending upon the setting of a code selector switch, electronic circuit constants within a transpondor cause it to reply to challenges at varying pulse durations for each of the sweeps. Thus, at the challenging station, the target's

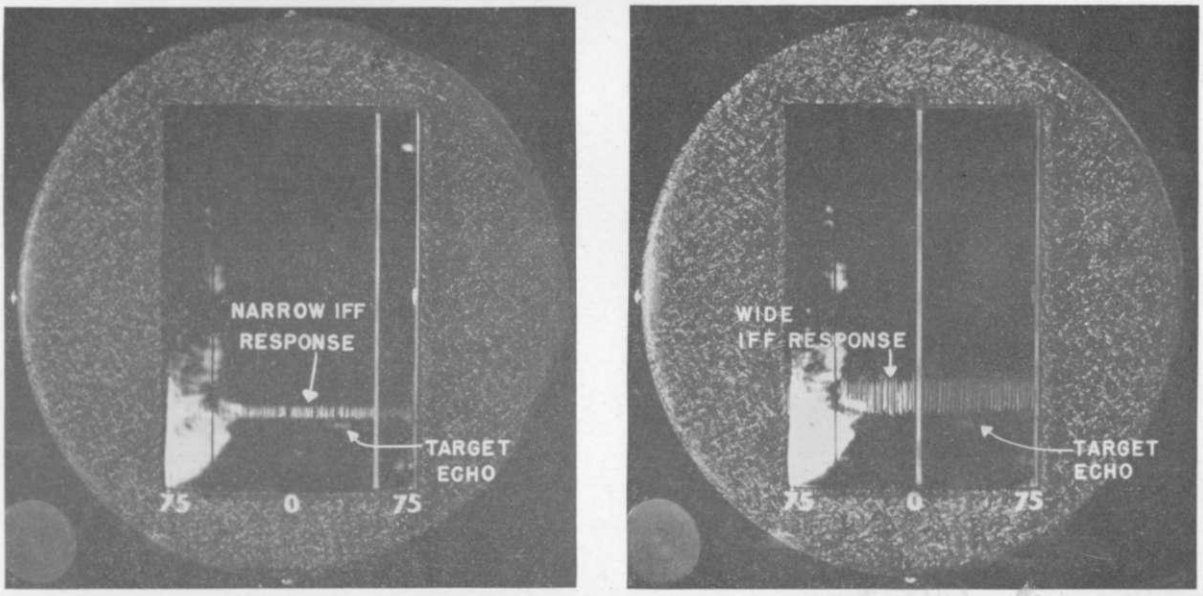


Figure 4–6.—Here's the IFF display on the APS–4 air-borne radar scope. When land masses or other large targets interfere with the observation of the IFF signal, the "gain" is reduced to wipe out the radar target, allowing the IFF signal to be clearly displayed.

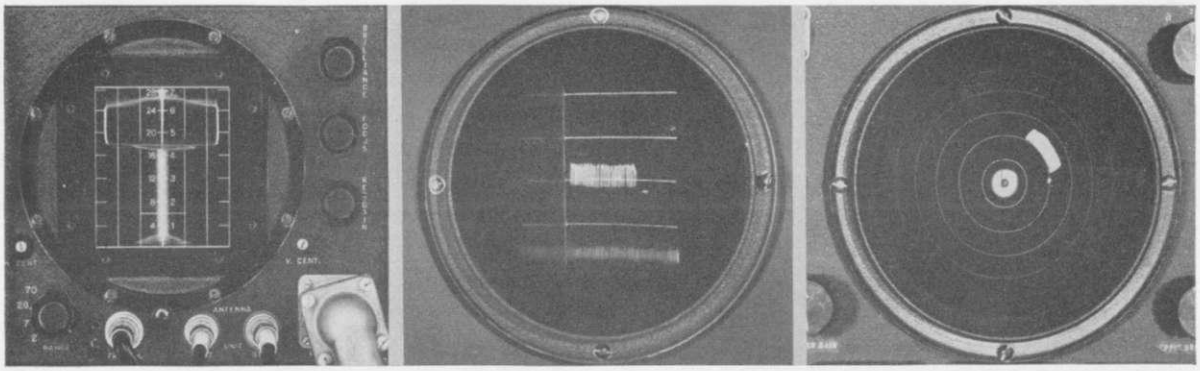


Figure 4–7.—Emergency (very wide) IFF signals as displayed on the L-scan (left), B-scan (center), and PPI-scan (right) indicator scopes.

IFF reply is viewed on the scope as a sequence of separate responses of varying widths, one each 3 seconds, which repeat themselves in series of four. The codes available are:

Selector switch	*Code widths*			
Position 1	NARROW	NARROW	NARROW	NARROW
Position 2	NARROW	BLANK	NARROW	BLANK
Position 3	NARROW	NARROW	NARROW	BLANK
Position 4	NARROW	NARROW	WIDE	WIDE
Position 5	NARROW	BLANK	WIDE	BLANK
Position 6	NARROW	NARROW	WIDE	BLANK

Recognition of a friendly target is thus insured by the fact that:

1. It returns an IFF response to a challenge:
2. The signal itself is gap-coded in accordance with codes established by fleet doctrine.

VI. TRANSPONDOR OPERATION

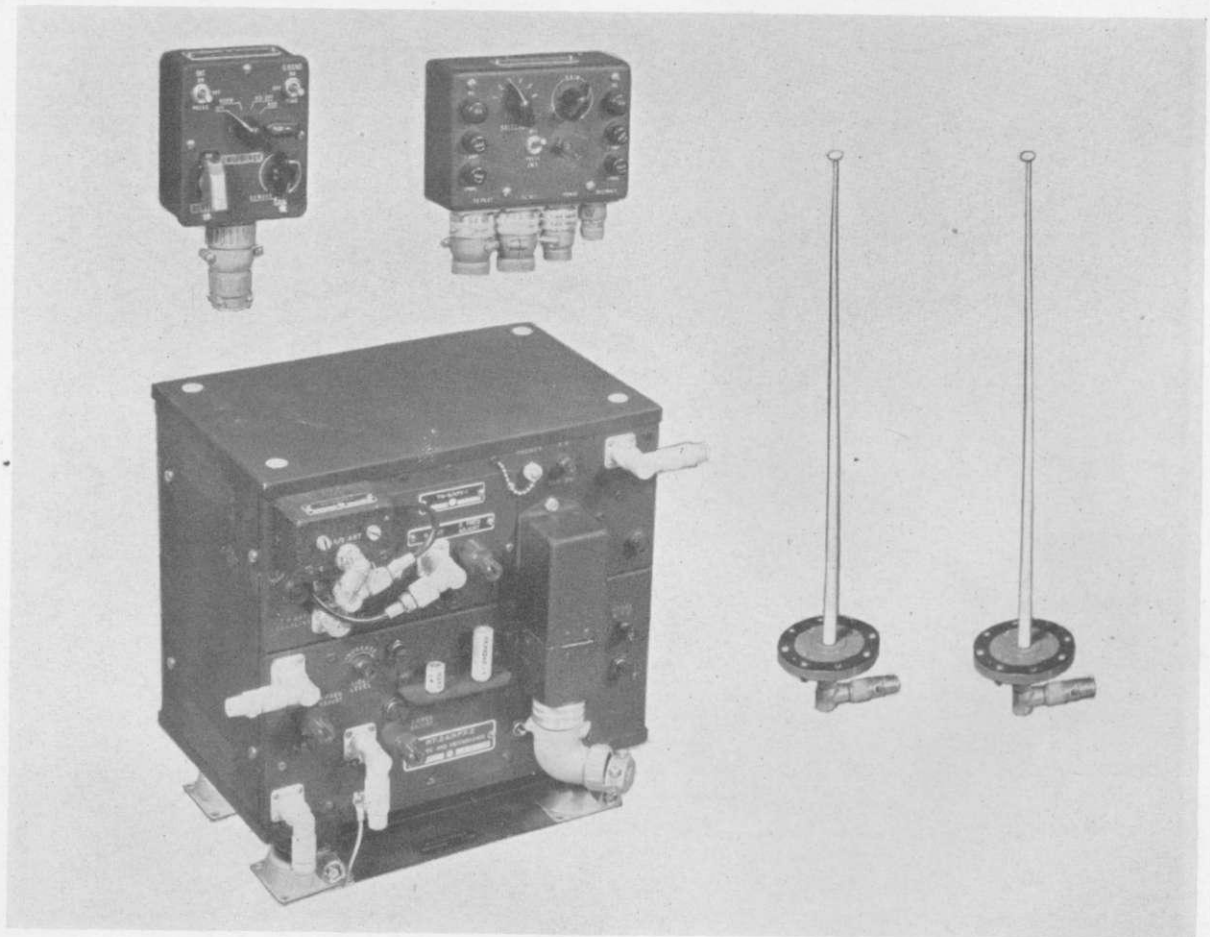
1. *A-band.*—Normal transpondor operation occurs on a band of frequencies from 157 megacycles to 187 megacycles, designated as the A-band.

2. *G-band.*—Certain aircraft (VF), in addition to establishing their identity to search radars on the A-band, must be quickly recognized by fighter-director activities. As the result of specific voice-radio requests, such VF aircraft transpondors can be switched from the normal A-band operation to a designated fixed frequency in the G-band of frequencies (194 megacycles to 212 megacycles), its G-band responses being displayed on the fighter director's PPI scope only.

3. *Emergency.*—In aircraft in distress, the IFF equipment can be set to respond to challenges so as to return pulses of exceptionally long duration once every 3 seconds. These are viewed on the scope (fig. 4–7) at the challenging station as very wide IFF signals, establishing the fact that the interrogated aircraft is in distress.

VII. INTERROGATOR-RESPONSOR OPERATION

The interrogator-responsor unit transmits challenges to other craft and receives replies from those that are equipped with the proper transpondor units. The frequency range of the I-R (interrogator-responsor) unit is 160 megacycles to 184 megacycles, and, while the interrogator and the responsor have separate tuned circuits they are normally tuned to the same frequency. Tactical considerations determine the exact frequency within this band, designated for use in a specific area or for a specific length of time.



AN/APX-2

AN/APX–2

(Transpondor-Interrogator-Responsor)

I. FUNCTION

A. Primary purpose. The two basic purposes of the equipment are to enable the aircraft in which it is installed:

1. To *identify* itself as friendly when it is challenged by appropriately equipped air, ship, and ground forces.

2. To *challenge* a radar contact to determine its friendly or enemy character.

B. Secondary uses. 1. AN/APX–2 can be used by aircraft in distress to transmit an emergency reply to interrogating stations. The character of the emergency signal as viewed on the scope of the interrogating stations indicates that the aircraft interrogated is in distress.

2. As the result of voice-radio instructions from CIC intercept officers, AN/APX–2 can be set for G-band transmission—a mode of operation wherein a 5-cycle blinking signal is transmitted on a specially designated frequency. The display of the G-band signal on the intercept officer's PPI scope furnishes an additional mode of aircraft identification and enables the intercept officers to differentiate between the aircraft so interrogated and others in the same group.

3. A further supplementary purpose of the equipment is to enable the aircraft in which it is installed to serve as a beacon on which other appropriately equipped aircraft can "home."

II. DESCRIPTION

A. Main components. AN/APX–2 consists of:

1. Two fixed, rodlike antennas, one for transpondor operation, the other for interrogator-responsor operation.
2. Transpondor unit.
3. Interrogator-responser unit.
4. Pilot's control unit.
5. Operator's control unit.
6. Impact destructor switch.
7. Connecting cables.

The transpondor and the interrogator-responsor form one unit of equipment. The top chassis of this unit contains the two-channel (A band and G/R band) transpondor and the bottom chassis contains the interrogator-responsor unit.

Receptacles are provided in the unit for screw-in destructors which can be exploded by throwing the destruct switch in the pilot control unit when there is danger of the equipment's falling into enemy hands. The impact destructor switch furnishes additional means for exploding the destructors by operating automatically upon impact, as in the case of a crash landing.

B. Mode of operation. 1. *Method of identification.*—The presence but not the identity of aircraft, ships, etc., may be detected over considerable distances by means of radar equipment. It is the function of IFF equipment to supplement radar detection and location by challenging the unknown craft for recognition as friend or foe, and conversely, to furnish identification upon challenge from other friendly craft. The operative method employed by IFF equipment is the transmission and reception of very short spurts (pulses) of continuous-wave radio-frequency energy. General identification as "friendly" is accomplished as follows:

(*a*) The challenging craft (or shore facility), after making radar contact, transmits a series of "interrogating" pulses.

(*b*) On reception of this series of interrogation pulses, the challenged craft (if appropriately equipped) automatically transmits a series of reply pulses, which are coded for special identification or tactical purposes.

(*c*) The coded reply is received by the challenging craft and displayed on the screen of a cathode-ray tube so that the coded sequence of IFF signals may be observed readily.

(*d*) The failure of an unknown craft to make a proper IFF reply, after it has been located by radar and challenged by IFF, classifies it as unidentified, and hence presumably an enemy.

2. *Associated equipment.*—Since AN/APX–2 equipment is designed to transmit challenges and receive replies, as well as to receive challenges and transmit replies, the use of associated radar or other indicator equipment is required. The IFF responses it receives may be combined with the radar display or viewed on a separate

indicator used to display IFF responses only. IFF responses indicate the range but not the azimuth bearing of the replying craft, so that exact recognition must be made by means of range associations between IFF responses and radar echoes.

3. *Beacon function.*—For the supplementary beacon use of the equipment, the same procedure of challenge and reply is followed, but the challenging or "homing" craft must be equipped with a directional antenna system so that accurate bearings can be taken on the aircraft that is employing the beacon operation of its AN/APX–2 equipment.

C. Special features. 1. *Transpondor.*—The upper chassis of AN/APX–2 is a two-channel (A- and G/R-band) transpondor unit which receives challenges and automatically transmits replies. The G/R-band tuning unit is included as an integral part of this chassis, but it is designed so as to be removable, and replaceable by a similar unit operating in a different frequency channel. This alternative tuning unit is not supplied as part of the AN/APX–2 equipment and is not discussed herein.

a. A-band.—The tuned circuit of the A band is motor-swept from 157 megacycles to 187 megacycles during a sweep period of 2½ seconds, following which there is a brief sweep-retrace of "flyback" interval (approximately one-third of a second in duration) before a new frequency sweep is begun. During the sweep, itself, interrogation pulses (challenges) can be received on any frequency in the A-band range, and reply pulses will be automatically transmitted, pulse for pulse, on the same frequency. These A-band replies are coded, so that in addition to providing general identification responses, the replies also may be used to communicate tactical information based on a predetermined code schedule.

Coding is accomplished by means of selected combinations of narrow pulses, wide pulses, and blanks. Four sweeps, or about 11 seconds, are required to transmit a code combination. Six combinations are available as determined by the setting of the selector switch on the operator's control unit.

The A-band also may be used for emergency operation, during which it transmits very wide ("distress") pulses which the challenging craft will immediately recognize as an urgent appeal for help.

b. G/R-band.—The separate tuned circuit of the G/R band is normally preset to a designated operating frequency within the G-band frequency range of 194 megacycles to 212 megacycles. However, by means of a bench adjustment (plugging in a "Rooster" capacitor), this tuned circuit may be preset to a designated operating frequency in the "Rooster" (IFF beacon operation) range of 172 to 182 megacycles. In either case, interrogation pulses are received only on the preset frequency, and replies are automatically transmitted, pulse for pulse, on the same frequency.

Neither G band nor Rooster band replies are coded, as the operating frequency chosen serves for special identification.

G-band operation is not used as a substitute for A-band (general identification) operation, but serves as an additional function for special fighter plane control purposes.

Rooster band operation is used only for the special "beacon" purpose.

c. Concurrent operation A-G bands.—Concurrent operation of the A and G bands is made possible in the equipment by sharing operating time. The time-sharing circuit cycles at the rate of about 5 c. p. s., alternately switching the A-band off and on, while simultaneously switching the G-band on and off, so that the G-band and A-band operate alternately for intervals of approximately one-twentieth and three-twentieths of a second, respectively.

Time-sharing operation of the two bands is initiated whenever the G-band switch is thrown on while the A-band is operating (master control switch in the Norm position).

Time-sharing begins immediately, but does not cease the instant the G-band switch returns to its OFF position. A "holding" circuit ensures the continuation of G-band (time sharing) operation for an interval of 10 to 20 seconds.

d. Rooster function.—When the G/R band has been adjusted and is used for Rooster operation, it operates continuously and the A-band is switched off.

e. Transpondor suppression.—All transpon-

dor operation (A-band alone, A and G bands sharing time, or Rooster alone) is suppressed during the very brief operative periods of the interrogator-responsor in the lower chassis. Additional suppression is also available, when required, to avoid interference with the operation of associated equipment.

NOTE.—It should be emphasized that the use of the word "operation" in connection with the transpondor unit does not necessarily imply that the transpondor is actually receiving challenges and transmitting replies. It is convenient to speak of "transpondor operation," but this means only that the transpondor is in an *operative state;* i. e., it is able to receive interrogations and transmit replies whenever and as long as it is actually challenged. If no challenges are received, nothing is transmitted (unless strong electrical noises should cause the transmission of false replies—a condition called "squittering"). On the other hand, when the transpondor is inoperative or suppressed, it is disabled from receiving challenges and from transmitting either true or false replies. Since the transpondor operates automatically (when it is in an operative state and challenged), the pilot and/or operator are relieved of the intolerable burden of making control adjustments every time their craft is challenged. Their craft may be continuously challenged and will continuously transmit replies without their even being conscious of it. Indeed, the only check they have on whether or not the transpondor is actually operating (once the controls have been set to put it in an operative state) is to plug headphones in the phone jack on the transpondor unit and listen for the characteristic sounds produced by received interrogations and transmitted replies in the various types of transpondor operation.

2. *Interrogator-responsor.—a. Mode of operation.*—The interrogator-responsor unit is located in the lower chassis of the AN/APX–2. This unit transmits challenges to other craft and receives identification replies from those that are equipped with the proper transpondor units. The frequency range of the I-R unit is 160 to 184 megacycles, and while the interrogator and responsor have separate tank circuits, they are normally tuned to the same frequency. Tactical considerations and fleet doctrine determine the exact frequency designated for use in a specific area or for a specified length of time.

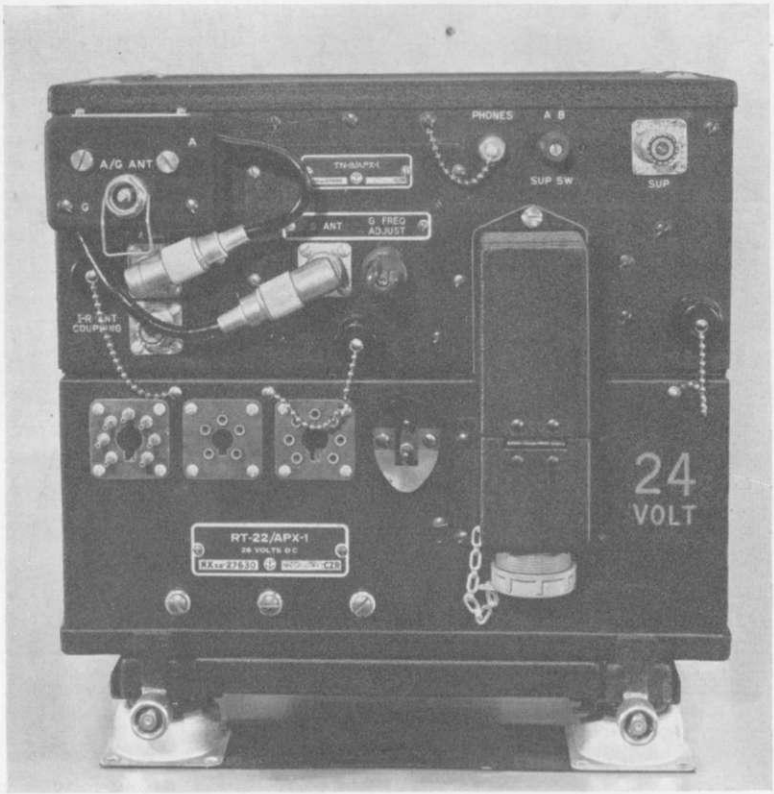
b. Interrogator.—Normally the interrogator-responsor unit is not kept in continuous operation (as is the A-band transpondor), but is thrown into operation by use of the INT switch, whenever the pilot or operator wishes to challenge an unknown craft whose presence is detected by radar or suspected.

c. Responsor.—The responsor is inoperative except for a brief "receptive period" immediately following each transmitted interrogation pulse. In high-power operation, the length of this receptive period is approximately 1250 microseconds, and in low-power operation it is approximately 125 microseconds. During these periods the responsor is enabled to receive reply pulses from challenged craft. The received replies are directed, amplified and delivered to the cathode-ray tube circuits of the associated radar or indicator equipment.

During each interval the interrogator-responsor is transmitting and receiving, all transpondor operation in the upper chassis is suppressed.

III. TACTICAL EMPLOYMENT

Refer to page 126.



AN/APX–1

(Transpondor)

I. FUNCTION

A. Primary purpose. AN/APX–1 is employed in aircraft for the purpose of receiving challenging signals from friendly ground forces, surface vessels and aircraft, and responding with a coded reply signal which identifies the aircraft in which it is installed as friendly.

B. Secondary uses. A supplementary use that can be made of the equipment—not possible unless an auxiliary control unit is used—is to enable aircraft in which it is installed to serve as a beacon on which other aircraft having suitable interrogation equipment (such as AN/APX–2 or AN/APX–8) may "home."

II. DESCRIPTION

A. Main components. The AN/APX–1 consists of the following:

1. A single, fixed, rodlike antenna.
2. A transpondor unit (receiver-transmitter).
3. Power supply unit.
4. Pilot's remote control unit.
5. Pilot's auxiliary control unit.
6. Selector unit.
7. Impact switch.

B. Mode of operation. Prior to flight, the selector switch unit is adjusted to provide proper coding as determined by fleet doctrine.

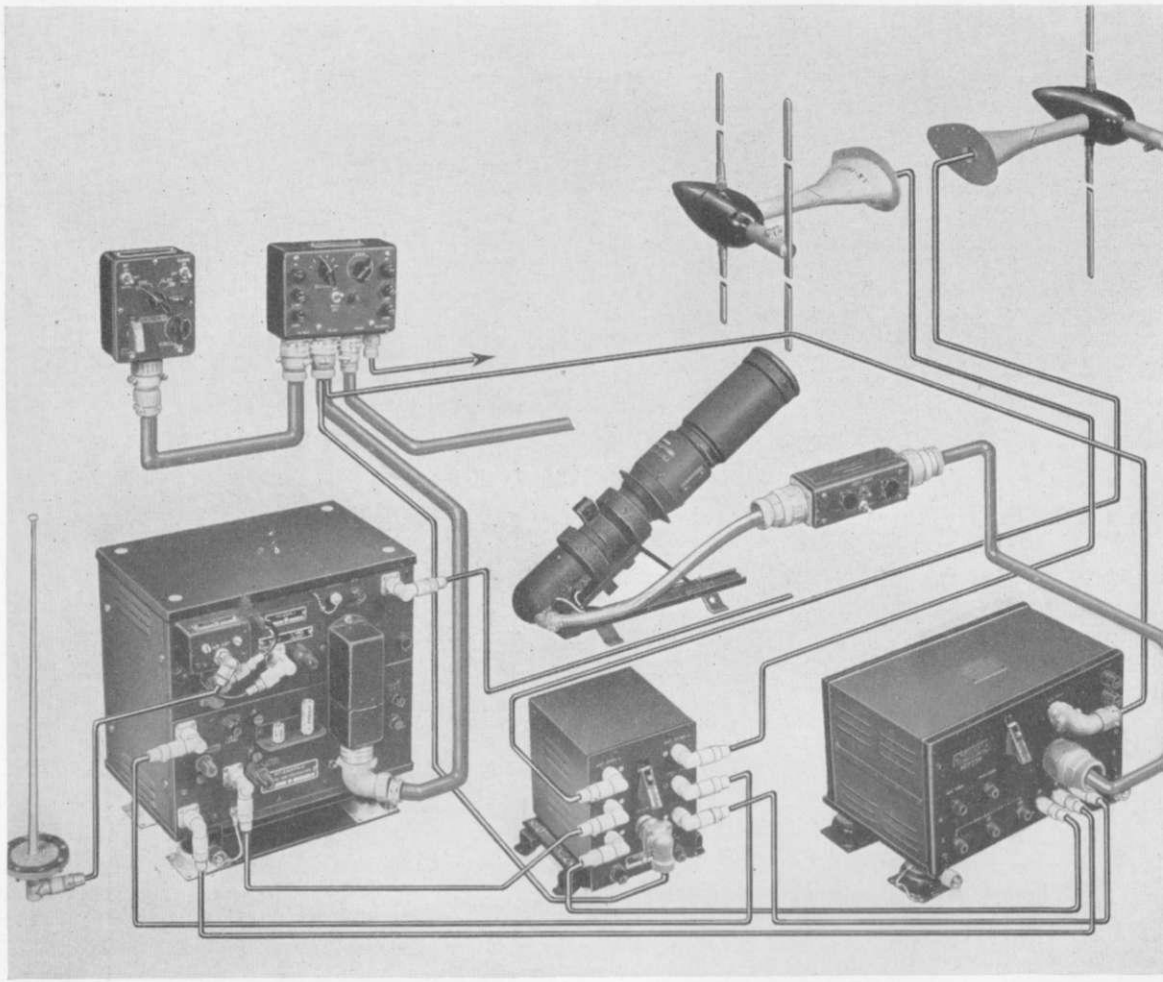
Control of the equipment is by means of the auxiliary and remote control switch units located in the pilot's cockpit.

In operation, the AN/APX–1 is similar in all respects to that of AN/APX–2, with one main exception; it will only *reply* to interrogations from other friendly craft (transpondor operation). It does not contain an interrogator-responsor unit and cannot challenge other aircraft.

(For transpondor operation of AN/APX–1, see Transpondor, AN/APX–2, p. 103.)

III. TACTICAL EMPLOYMENT

Refer to page 126.



AN/APX-8

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AN/APX–8

(Transpondor and Directional Interrogator-Responsor)

I. FUNCTION

A. Primary purpose. AN/APX–8 is an electronic identification equipment used for the purpose of interrogating radar-detected targets, and displaying the IFF response (if any) on its own scope screen to indicate the target's general bearing, as well as its range and identity. It can be used in non-radar equipped aircraft, or where a separate display of IFF signals is desirable.

II. DESCRIPTION

A. Main components. AN/APX–8 consists of a complete AN/APX–2 installation (see p. 106) plus the following AN/APA–1 units:

1. Control box.
2. Remote indicator-amplifier.
3. A viewing scope.
4. An antenna switching unit.
5. Two fixed directional antennas.

B. Mode of operation. 1. *Directional feature of AN/APX–8.*—The AN/APX–2 part of the installation functions as before:

(*a*) To respond to interrogations from other craft (transpondor operation).

(*b*) To interrogate other craft and display the response on the scope of the parent radar.

Because of the omnidirectional radiation and reception characteristics of AN/APX–2, the visual response appears on the radar scope correct only with respect to range and identity. The bearing of the target is not indicated. If, for example, two targets are at the same range but at different bearings, a single IFF response will indicate that one is friendly while the other ostensibly is a bogey (or skunk). But lacking bearing information it will not be possible to identify the friendly from the bogey.

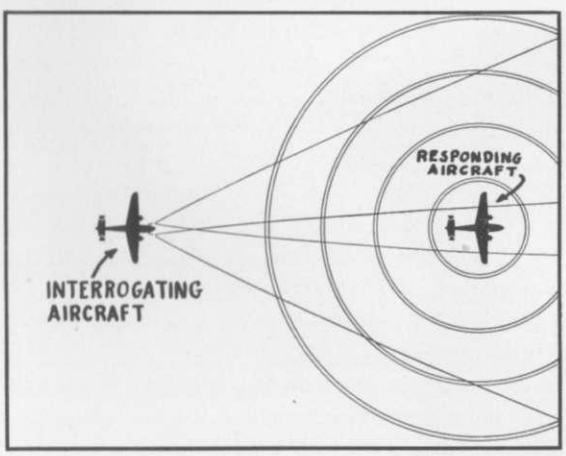

Figure 4–8.—Directional antennas and a lobe-switching device on the interrogating aircraft equipped with AN/APX–8 enable it to receive the IFF responses from the target aircraft and determine its relative bearing.

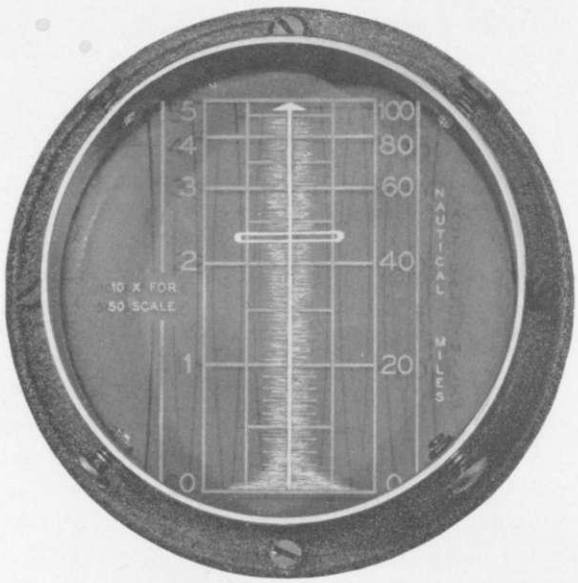

Figure 4–9.—The IFF response as displayed in the APX–8 indicator. When the target is dead ahead, the IFF blip appears centered about the trace.

With the addition of the AN/APA–1 equipment to the AN–APX–2 installation, (making the combination an AN/APX–8), the interrogator's challenging signals are transmitted directionally toward an observed radar target by turning the aircraft in the direction of one of the radar targets. The response (if any) appears on the APA–1 L-scan type of scope. The lateral disposition of the response blip on the trace indicates the bearing of the target furnishing the response, relative to the interrogating aircraft's heading. See figures 4–8 and 4–9.

2. *Operating ranges.*—AN/APX–8 can be set for any one of three operating ranges of 5, 50, and 100 miles by the use of a 3-position toggle switch located on the control unit.

A plexiglass scale, located over the face of the AN/APA–1 viewing scope assists in judging the approximate range of a target's IFF response.

III. TACTICAL EMPLOYMENT

See below.

TACTICAL EMPLOYMENT OF IFF

I. FACTORS APPLICABLE TO TACTICAL EMPLOYMENT OF ALL MARK III IFF EQUIPMENT

1. The Mark III IFF equipment is an aid in determining the friendly or enemy character of a target, and cannot be relied upon to give 100 percent identification. All possible means of recognition are to be used in conjunction with IFF, particularly in regard to planes operating in battle areas. Operating personnel must be alert to the limitations of the IFF system, and support it with an up-to-the-minute understanding of the existing tactical situation. It must also be realized that the mere fact that one's own ship has identified the target is no proof or assurance that the target has identified the ship. IFF is an additional means of identification; all other means of identification and recognition must be used with special emphasis being placed on alert lookouts.

2. Although six different codes (exclusive of the emergency indication) are available, their characteristics are such that they are not readily distinguishable when two or more transponders are operating at approximately the same range. Their characteristics depend on a combination of wide and narrow blips occurring during a 12-second cycle. Thus, when a large number of transpondors are in operation a confused picture is presented to the radar operator. Practically, under these conditions the radar operator can recognize that responses consist of:

(*a*) All narrow blips.
(*b*) A combination of narrow and wide blips.
(*c*) Emergency signals.

When operating ship-borne radar equipment on long range (375 miles), distinction between narrow and wide blips is difficult, and emergency signals (very wide) are the only ones readily identified.

3. At the present time IFF antennas have either very limited directional characteristics or are entirely nondirectional, and replies should be expected over a wide variation in bearing. Thus it is possible for an enemy contact to be indicated as friendly if it is at the same range as a friendly craft on a different bearing. Due to this bearing limitation, the Mark III has no reliable value in a melee. In view of the above, it must be realized that the bearing resolution of IFF is nonexistant for all practical purposes, and that the range resolution is the only sure means of determining whether an IFF response is emanating from a given target. The range resolution of IFF in most cases is determined by the radar display and therefore every effort should be made to use the most expanded scope available.

4. There is a possibility that the effectiveness of transmissions of transpondors or interrogators may be reduced by either ship or aircraft structure in the proximity of the associated antennas.

5. In the air, pilots are normally unable to determine definitely whether their transpondor is functioning properly.

6. A sense of false security must not be permitted because many friendly blips from a group of planes can be seen on the radar screen. It is quite possible for enemy planes to trail such a group and attempt to take advantage of their transpondors to press home an attack. It is also possible for blips from friendly aircraft to conceal blips from enemy surface craft.

7. The possibility that the transpondor on a challenged ship or plane may be out of commission or may not be turned on must always be considered.

8. The possibility that the enemy may have similar or captured equipment must be considered.

9. It is necessary, in areas which are known or believed to be within the coverage of enemy radar apparatus and which are also covered by friendly radar, to strike a balance between the advantage of keeping IFF switched on to assist identification of friendly forces as compared to danger which may arise from detection of IFF by the enemy. It is to be noted that several known types of Japanese surface and air-borne radars will trigger the Mark III IFF, and that use of transpondors when in the vicinity of known enemy short installations or major fleet units must be goverened accordingly. Moreover, the advantages of positive identification to friendly submarines must be recognized.

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CONFIDENTIAL

PART FIVE

NAVIGATION SYSTEMS

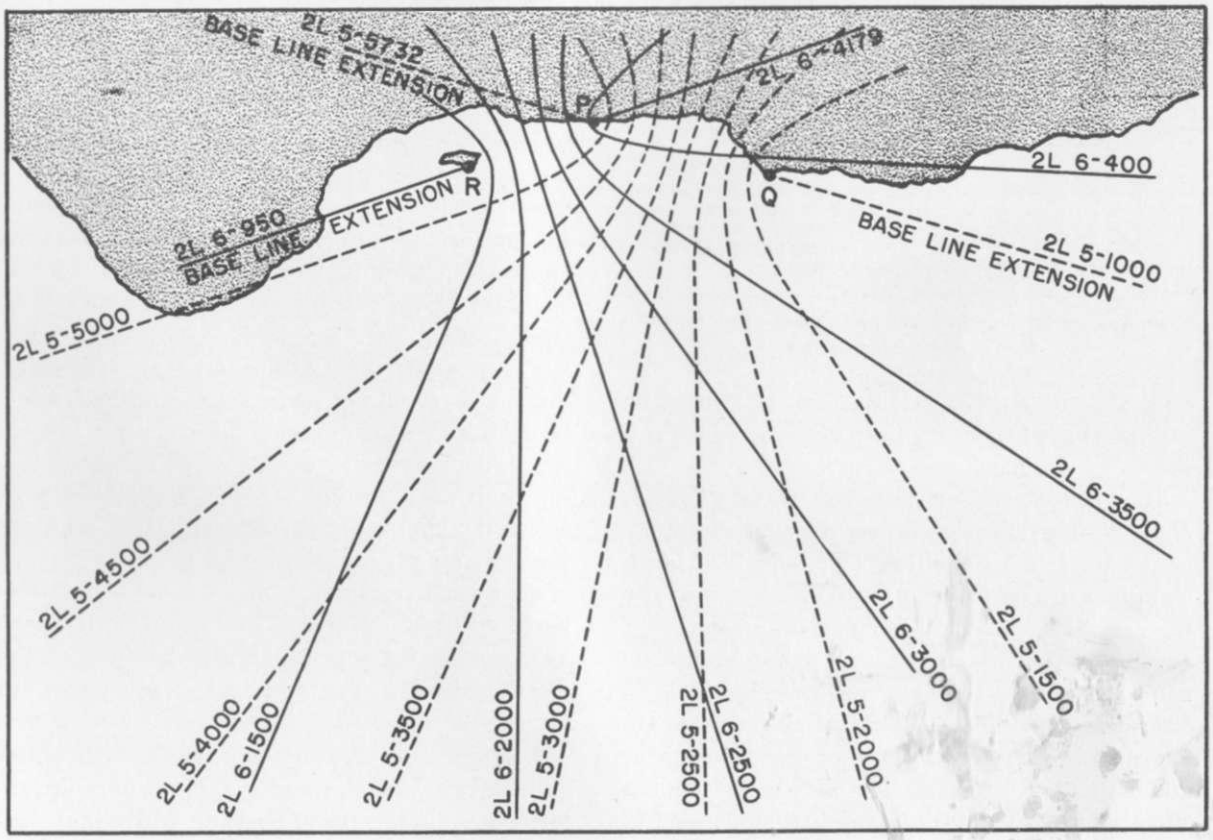
LORAN (STANDARD)

I. PRINCIPLES OF OPERATION

A. A General description of loran. The accuracy, range and speed of use of loran surpass that of most other navigational aids. The basic principle is simple. Pairs of radio stations transmit signals on the same radio frequency. Transmissions of signals is not continuous, but intermittent, each station sending out at regular intervals a short signal, or pulse, followed by a comparatively long interval of silence. These pulses are radiated in all directions from the transmitting stations and travel at a constant speed, 161,800 nautical miles per second (approximate). The pulses from a given pair of stations are synchronized so that there is a definite time difference in their arrival at any geographical point. This time difference of arrival is measured in microseconds (millionths of a second) and is constant for all points on the earth's surface whose difference of distance from the two stations is the same. The focus of all points having a given time difference is a hyperbolic curve known as a loran line of position. See figure 5–1. Special loran charts have been printed which show these lines of position for all station pairs now in operation.

With the loran equipment the navigator measures the time difference in the arrival of a pair of pulses at his position. From a loran chart he determines directly his line of position

Figure 5–1.—Families of hyperbolas from the loran stations. "P" is a double-pulsed master station common to both pairs. "Q" and "R" are slave stations.



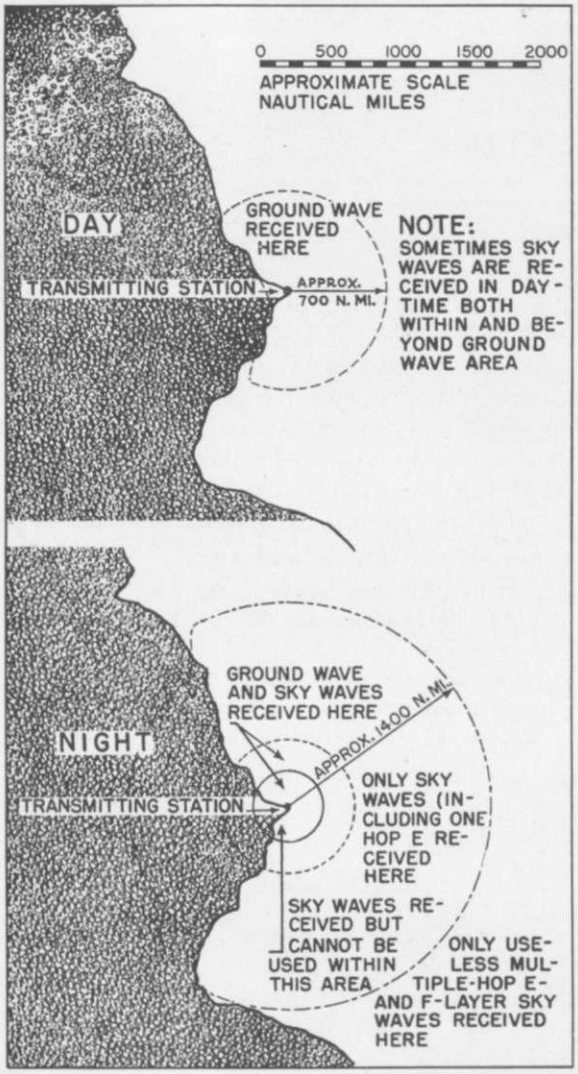

0 500 1000 1500 2000
APPROXIMATE SCALE
NAUTICAL MILES
DAY
GROUND WAVE RECEIVED HERE
NOTE:
SOMETIMES SKY WAVES ARE RECEIVED IN DAYTIME BOTH WITHIN AND BEYOND GROUND WAVE AREA
TRANSMITTING STATION
APPROX. 700 N. MI.
GROUND WAVE AND SKY WAVES RECEIVED HERE
NIGHT
APPROX. 1400 N. MI.
ONLY SKY WAVES (INCLUDING ONE HOP E RECEIVED HERE
TRANSMITTING STATION
SKY WAVES RECEIVED BUT CANNOT BE USED WITHIN THIS AREA
ONLY USELESS MULTIPLE-HOP E- AND F-LAYER SKY WAVES RECEIVED HERE

Figure 5–2.—Daytime and nighttime zones of signal reception from a single loran station.

on the earth's surface, without calculation. The intersection of two such lines determines a loran fix.

B. Advantages of the loran system. 1. *Range.*—The effective range of loran varies between 500 and 1,400 miles. Two types of loran signals are received, ground waves and sky waves. The maximum effective range of ground waves over sea water is about 500 to 700 nautical miles in the daytime, and about 350 to 500 miles at night. Usually, sky waves are present only at night, but they are received at much greater distances so that the maximum effective range of loran at night is extended to between 1,200 and 1,400 nautical miles. See figures 5–2, 5–3, and 5–4.

Many factors affect the useful range of radio waves, such as weather conditions, time of day or night, time of year, frequency of transmission, power output of transmitting stations and the nature of the earth's surface (land or water). Most of these factors are beyond the scope of this discussion. With the power and frequencies now used, standard loran is primarily an over-water system of navigation, and the range values given are average values for transmission and reception over sea water. Over land the effective range is reduced, varying between 70 and 150 nautical miles for ground waves and between 1,000 and 1,300 nautical miles for sky waves.

2. *Accuracy.*—Defining the accuracy of loran in a generalized statement is somewhat difficult as too many factors are involved. The accuracy with which a loran line of position can be obtained depends primarily upon the type of signals (ground or sky waves) and the location of the aircraft relative to the two transmitting stations. Other factors are weather conditions, accuracy of station synchronization, accuracy of the charts, and skill of the operator.

3. *Times required to obtain a fix.*—Under favorable conditions, a skilled operator can obtain a reading (time-difference measurement) for a line of position in less than a minute. Readings for two or three lines of position may be taken and the position of the fix plotted within 3 to 5 minutes. Under the most unfavorable conditions, obtaining a single time-difference reading may require 3 or 4 minutes. Once the time-difference readings have been obtained, plotting the lines of position is a simple process which the average operator will accomplish easily in 2 or 3 minutes. In comparison with celestial navigation, the average time required for a loran three-line fix is 3 to 5 minutes, as against the average time of a three-line celestial fix of 20 to 25 minutes. The speed with which an accurate fix may be obtained is one of the most valuable characteristics of loran in aircraft.

4. *Homing.*—Homing is possible with loran, as in other forms of radio navigation. Loran, however, offers one important additional fea-

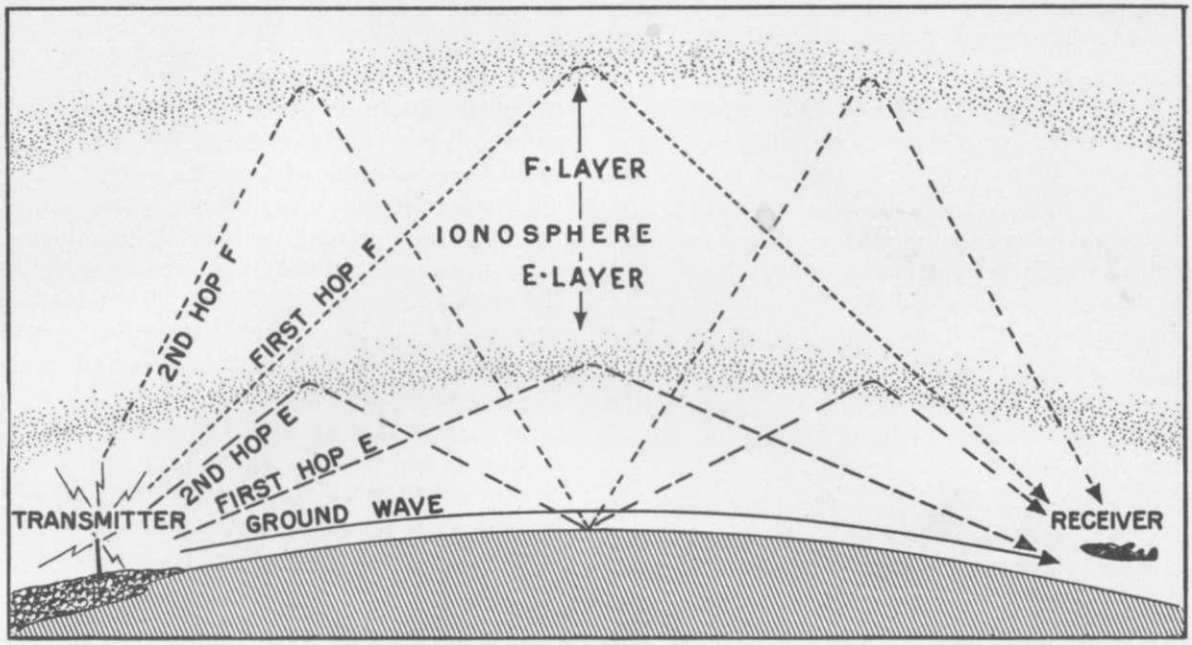


Figure 5–3.—Depending upon the time of day or night, loran signals may follow a ground path (ground waves), they may be reflected from ionosphere layers (sky waves), or there may be a combination of received signals consisting of ground and sky waves.

ture: it is possible to home to any *geographical point* within range of the transmitting stations. The advantages of this characteristic are obvious when compared to the RDF or radio compass with which homing is restricted to a course toward the transmitting station.

5. *Effect of adverse weather conditions.*—The reliability of loran readings is only slightly affected by adverse weather conditions. Severe magnetic disturbances may prevent the use of weak signals, but normal electrical disturbances merely increase the difficulty of obtaining a good reading. The accuracy of the reading may be affected to some extent, but the reading can nearly always be used if consideration is given to its probable error. The weather at the point of reception is of little consequence, and readings may be obtained almost as easily in rough air as in smooth.

6. Radio silence.—Radio silence may be maintained at all times because no signals are transmitted from the aircraft. The aircraft merely receives the radio signals broadcast by the transmitting station, hence it does not expose its position to the enemy. This is an important factor in wartime.

7. *Effect of directional distortion negligible.*—Loran measures the *time difference* of arrival of radio waves rather than *direction* of arrival. Directional distortion may be disregarded as no bearings are taken or received in order to determine the position of the aircraft. The difference in arrival time of loran signals due to directional distortion is negligible first, because the angular distortion increases the time of travel by a very small amount, and, second, because both signals are usually subject to the same increments.

8. *Accuracy not dependent upon the aircraft's compass or chronometer.*—Loran lines of position are fixed with respect to the earth's surface. Thus they are independent of compass error and correct observatory time—two factors critical in radio and celestial navigation

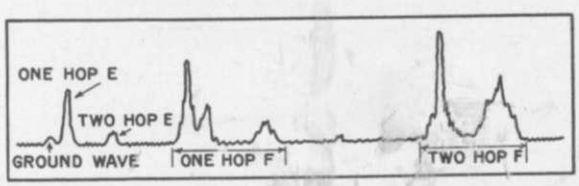


Figure 5–4.—From left to right, above, is shown the order in which the various kinds of loran signals will appear on the scope.

respectively. A system which is independent of these two factors possesses obvious inherent advantages.

9. *Restricted use.*—Part of the time difference in the reception of the two signals is a coding delay whose purpose is to restrict the use of loran to friendly aircraft. Loran charts and tables have been computed for a fixed value of this coding delay; but, if necessary, it is possible to change the delay and issue to all navigators a correction value to be applied to all readings before plotting lines of position. Up to the present date there has been no change in the coding delay and no coding correction values have been issued.

10. *Secrecy and isolation of transmitting stations.*—Transmitters cannot be used by the enemy as beacons to direct their aircraft to vital areas because stations are located in isolated positions. Furthermore, enemy detection of the location of individual transmitting stations is difficult because all stations in an area operate on one radio frequency.

11. *World-wide coverage.*—Although some of the advantages of loran are of great value in wartime, its fundamental advantages are primarily navigational. These will continue to be of great importance in peacetime.

12. *Simple antenna system.*—Loran operates with simple straight-wire antennas, either fixed or trailing, which eliminates complications of rotating loops and other directional types of antenna arrangements.

C. Limitations of loran. Navigators must remember that loran is only a new method of determining a line of position. It is not a substitute for navigation, but rather an excellent navigational aid. Intelligent use of loran requires an understanding of its limitations as well as its advantages.

Loran is a complex piece of electronic equipment containing 43 vacuum tubes. It requires attention and care, and is of necessity relatively fragile. In flight, voltage regulation and temperature changes are uncertain, which may change the alignment. Also, constant vibration over a period of time may change any of the screw driver adjustments. However, under normal conditions, only slight adjustments will be necessary and these can be made in a very few minutes.

D. The loran equipment. 1. *Transmitting stations.*—Loran transmitting stations for long-range, over-water navigation are usually located at prominent points along a coast line or on small islands. The distance between them normally ranges from 200 to 600 nautical miles, with approximately 400 miles considered the optimum from the standpoint of coverage and accuracy. If the geographical situation is unfavorable, the separation may be as small as 100 miles or as great as 600 miles.

Each pair of stations whose signals are synchronized has its own set of fixed lines of position. They are so located that two or more pairs of stations cover strategic areas, with the lines of position intersecting at favorable angles for obtaining accurate loran fixes.

In order to economize on station installations, one station may be made common to two pairs. In this case it sends out two entirely distinct sets of signals, each set being synchronized with the signals from an adjacent station. From an operating standpoint, however, a common station may be regarded as two separate stations at one location. A number of pairs covering the same general geographical area may operate on the same radio frequency and constitute what is called a "chain," even though some of the station pairs are independently located. In any chain operating on the same radio frequency, identification of a given pair is accomplished by control of the pulse frequency at which the two stations transmit their signals.

2. *Equipment carried in the aircraft.*—Airborne loran equipment consists of a loran radio receiver, an electronic time-measuring unit known as the loran indicator, special loran charts, and loran tables.

The loran radio receiver is a superheterodyne receiver in which loran signals are detected, amplified, and then passed to the loran indicator. The receiver and power supply form an integral unit containing a total of 16 radio tubes mounted in one cabinet.

The loran indicator is an electronic "stop watch" which measures, in millionths of a second, the time difference in the arrival of a pair of pulses. It is a unit containing a cath-

ode-ray tube and 26 vacuum tubes, mounted in the second cabinet of the installation.

The two units are connected by means of special cables. With the connecting cables, the total weight varies from 73 to 85 pounds.

Loran charts are an essential part of the system when loran equipment is used in aircraft. They enable the operator to translate the time differences directly into lines of position. The lines of position for each pair of stations are printed in separate colors and are clearly marked for easy identification. Loran charts are equal in importance to the equipment itself.

Loran tables containing data for plotting loran lines of position are used when loran charts are not available. Tables are preferred by some navigators on surface vessels, who prefer to utilize their usual plot sheet and put the loran fixes thereon.

II. OTHER LORAN SYSTEMS*

A. Introduction. In addition to the standard loran system, which is intended primarily for over-water navigation, there are three variations of it which have assumed prominence. They are: the SS loran system, the AT loran system, and the mobile loran system. The SS and AT systems were developed particularly for navigation use over inland areas.

B. The SS loran system. The sky-wave synchronized loran system (SS loran) was developed primarily to provide accurate loran coverage over large land areas, but it may be used equally well over water when it is desired to secure a high degree of accuracy over a large area. The principal disadvantages of the SS loran system are that it operates only at night when sky waves are consistently available, and will not work on nights when propagation conditions are so erratic as to make synchronization impossible.

In the SS loran system, the two stations in each pair are separated by a distance of approximately 1,000 statute miles. This is far too great a distance to permit synchronization by means of the ground wave, even over sea water. Instead, the stations are synchronized by the first-hop-E sky wave. Since the sky wave is propagated almost as well over land as over water, the use of the sky wave for synchronization permits the system to be set up over inland areas.

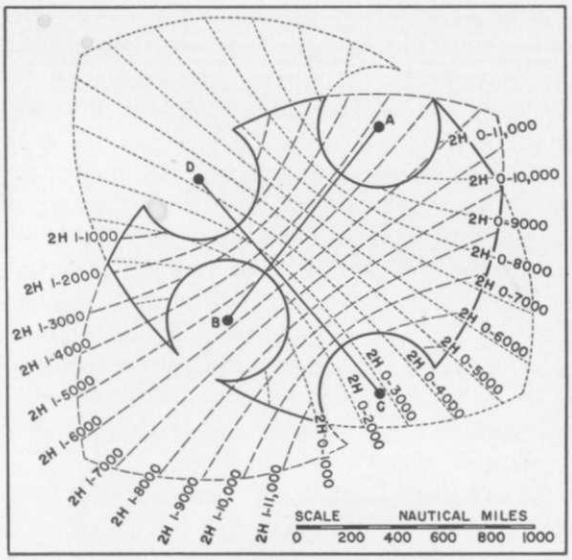


Figure 5–5.—Typical layout of an SS loran system. Stations "A" and "B" form one pair, stations "C" and "D," the other. The area enclosed by the solid line constitutes the service area.

A typical layout of stations for the SS loran sytem is shown in figure 5–5. The small circles around each station bound areas within which it is inadvisable to use the sky wave because of proximity to the stations. The useful service area of the system is shown within the solid line. It will be noted that the SS loran system permits the stations to be placed on opposite sides of the service area. This straddling of the objective places the region of greatest accuracy directly over the objective, and, in addition, introduces favorable crossing angles. The net result is that fixes accurate to about 2 miles or less are available throughout the service area, with the best accuracy located directly in the center of the service area.

SS loran has proved to be one of the most important adaptations of the standard loran system. Stations set up many miles away from enemy positions provide lines of position covering enemy territory. In some cases occupation of certain positions by the enemy makes it difficult to place the SS loran transmitters in ideal locations. Complete coverage of enemy-held

*Excerpts from BuShips Loran Manual No. 278.

territory may be impossible. Nevertheless, lines of position from a single pair may be invaluable. Accurate approach to enemy targets can be made by using the homing procedure previously explained.

In order to obtain fixes, single SS lines of position may be combined with lines of position obtained by some other means. An important tactical use combines loran and radar search or bombing equipment. A loran line of position passing through a prospective radar target is selected for homing and the radar screen is observed until the target comes into view. This procedure is particularly useful in approaching islands, coast lines, and cities.

C. AT LORAN. The air-transportable loran system (AT loran) differs from standard loran only in the form of equipment used in the ground stations, and in that shorter base lines are used. The AT loran ground station electronic equipment is of lower power and is considerably lighter in weight and smaller in size than the standard loran ground station equipment. Sinc standard loran ground station equipment. Since speed is the essence of AT loran operations, there is usually no time for the preparation of charts by the advanced methods used by the Hydrographic Office. Nor is there time for the transportation of such charts from the United States to the operating theater. Attached to each AT loran system is a group of trained computers and draftsmen, and reproduction equipment to prepare charts in the field. The speed with which such charts can be computed and drawn is greatly enhanced by the use of a polyconic or Lambert projection. The charts supplied for AT loran operations are of this variety. They are based on the existing aeronautical charts of the region, in the scale of 1:2,000,000 (about 32 statute miles to the inch).

In all other respects, so far as operation of the aircraft equipment is concerned, the service supplied by AT loran equipment is the same as that supplied by the standard loran equipment. The ground-wave accurate service range of the AT loran transmitters is several hundred miles less than that of standard loran, due to the short base lines and the lower power output.

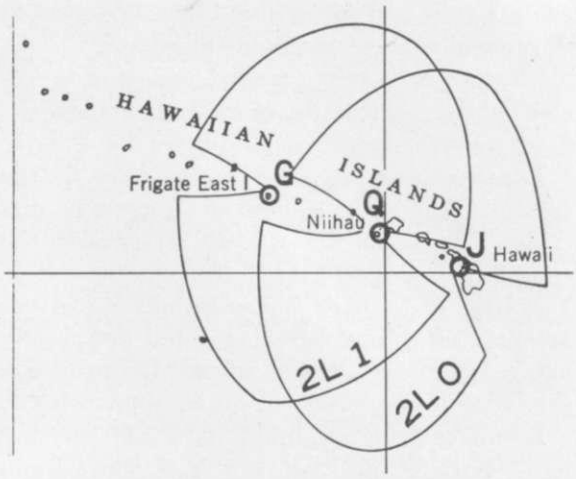


Figure 5–6.—On loran service charts the solid lines showing ground or sky-wave coverage are labeled to indicate the frequency channel, the basic recurrence rate, and the station pair number.

The sky-wave accurate service range is about the same as the ground-wave range. The signals will be usable with very low accuracy to distances of 1,000 to 1,400 miles.

D. MOBILE LORAN. Mobile stations are ones using a standard station apparatus housed in automobile trucks, equipped with surveying and chart providing facilities, and organized with especially trained personnel equipped to go into a remote location, have stations on the air, charts provided and giving service in one month. They are therefore suited to providing quick, temporary service. They are equivalent to standard stations in all respects apparent to the user of the service.

III. LORAN CHARTS AND BASIC INFORMATION

A. LORAN FREQUENCY CHANNELS. Four operating frequencies have been assigned for loran transmission. These channels, designated for reference as 1, 2, 3, and 4, are as follows:

1—1,950 kc.
2—1,850 kc.
3—1,900 kc.
4—1,750 kc.

There may be as many as eight pairs of transmitting stations employing any one frequency channel. Each of the pairs, however, will pulse at a different rate, enabling the equipment at the receiving location to be synchronized to receive and match only the selected pair.

B. Pulse recurrence rates. Two basic pulse recurrence rates are used, designated as follows:

L (low—25 per second.
H (high)—33⅓ per second.
(additional basic rates may be added.)

Any eight-station chain may employ a given basic pulse recurrence rate, each one of the eight pairs differing slightly in recurrence rate from 25 to 25 7/16 pulses per second for the low rate and 33⅓ to 34⅓ pulses per second for the high rate.

C. Legends. With reference to the loran coverage charts (see fig. 5–6), the legend designating the coverage provided by any designated station pair may be as follows:

2L 1

where "2" denotes the second frequency channel, 1,850 kilocycles; "L" denotes low basic recurrence rate, 25 per second; "1" denotes station pair recurrence rate.

On the loran charts, each of the station pair hyperbolas is similarly designated and in addition bears the time line designation, thus:

2L 1—4,500

D. Charts. Loran charts are published by the Hydrographic Office or the Aeronautical Charts Service, USAAF, for use aboard ships and aircraft. Ground-wave lines of position from the various station pairs are printed in distinguishing colors and are further identified by the legends described above. Line of position are shown at the closest interval of time (in microseconds) satisfactory for the scale of the chart. This varies between 100 and 10 microseconds.

In some areas, where five or six rates overlap, only the three or four most useful ones are plotted on the charts.

As basic information the loran charts carry isogonic lines, the location of radio stations, and aircraft facilities. Soundings are not shown.

Charts are available on several scales. The various series designations are:

Series	
VL–70	70 nautical miles per inch at mid. latitude.
VRL–200	About 60 nautical miles per inch.
VL–30	30 nautical miles per inch at mid latitude.
VL–15	15 nautical miles per inch at mid. latitude.
N (North Pacific)	15 nautical miles per inch at mid. latitude.
NW (North Atlantic)	1° longitude is 4 inches.

Note: For reference purposes, a series of chartlets, showing loran signal coverage for all loran stations now in operation have been included in the appendix, appearing at the end of this book. These chartlets are from the U. S. Navy Hydrographic Office publication 1–L (c), entitled "Loran Charts and Service Areas."

LINE VOLTAGE
4 AMP. 250V SPARE
SC 35704
R-98/APN-4
INDICATOR
INPUT SUPPLY
CHANNEL
POWER
COARSE DELAY
DUAL LIGHT
FINE DELAY

AN/APN-4

NOTE: There are three models of air-borne loran gear in current use. Excepting for circuit improvements, there are no fundamental differences in the receiver (RA) units. There are, however, marked operational and scope display differences in the indicator (ID) units (ID–6, ID–6A, ID–6B AN/APN–4). The ID–6 indicator, an early model, was used primarily for reception of stations operating on the 25-cycle repetition rate. Also, it presented a "dot" alignment pattern on the scope. The ID–6A retains the "dot" alignment pattern but is provided with a front-panel switch for setting the gear either to the 25- or 33⅓-cycle signal repetition rate. Indicator ID–6B is similar to ID–6A excepting that the alignment pattern is of the characteristic "stairs" type.

AN/APN–4 (AIRBORNE LORAN)

I. FUNCTION

A. PRIMARY PURPOSE. AN/APN–4 air-borne loran is an electronic device specifically designed for the purpose of receiving and measuring the time-difference in the arrival of pulsed signals from specially located shore-based loran transmitters.

Hydrographic Office loran charts, used in conjunction with the time-difference information, allow the navigator to determine the aircraft's line of position, or, with several lines of position, an actual "fix."

B. SECONDARY USES. 1. Depending upon the geographic location of a selected target within the loran signal transmission coverage area, a line of position, or combinations of lines, can be chosen as a course for the aircraft to "home" on the selected target.

2. In conjunction with other navigational information, loran time readings can be employed to determine accurately drift and wind at various altitudes, irrespective of visibility or weather.

II. DESCRIPTION

A. MAIN COMPONENTS. An AN/APN–4 installation consists of:

1. Superheterodyne receiver-power supply unit.
2. Indicator unit.
3. Fixed, or trailing wire antenna.
4. Connector cables.

1. *Receiver-power supply unit.*—One unit houses both the superheterodyne receiver and the power supply. Primary source for the power supply is taken from a 115-volt, 800-cycle aircraft alternator. The power supply converts this to the various voltages required for operation of the receiver and indicator circuits.

The receiver has four "fixed-tune" channels which must be preset to operate in designated frequency channels, depending upon the global area in which the equipment is to be used.

2. *Indicator unit.*—The indicator unit contains the cathode-ray tube upon whose screen the signals picked up by the receiver are displayed and measured. The indicator unit also contains those electronic circuit features and controls which permit:

(*a*) The selection of any one of eight pairs of transmitting stations operating within a given frequency band.

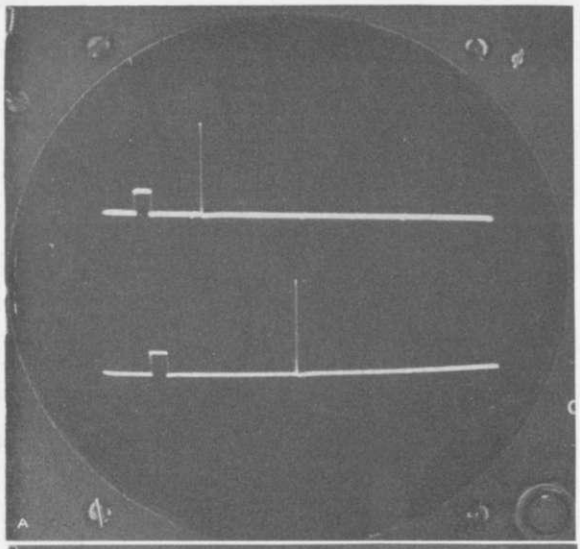
(*b*) The viewing of signal, time-measurement, and calibration screen displays.

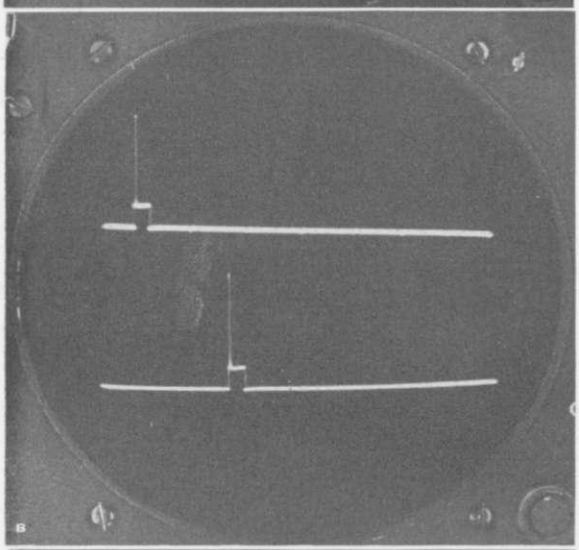
(*c*) Matching of the signals.

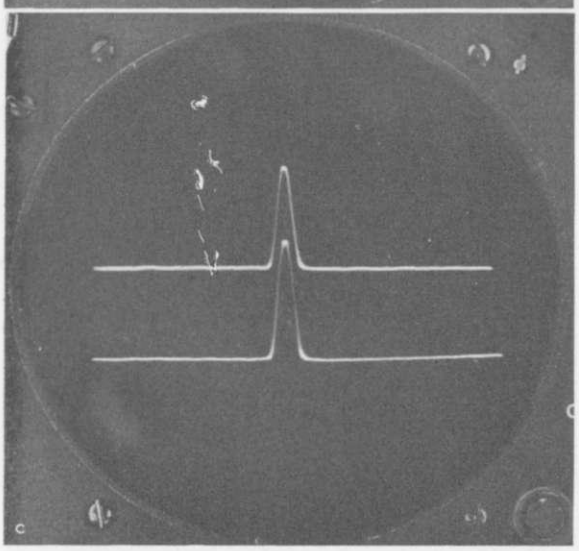
(*d*) Adjustment of signal gain and signal amplitude balance.

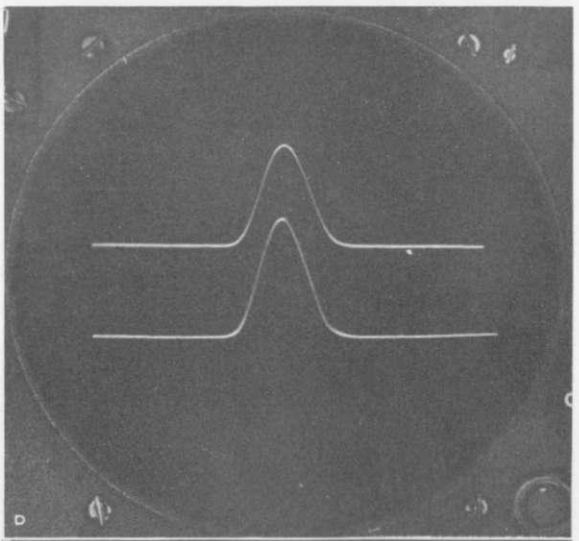
(*e*) Screwdriver calibration adjustments.

B. SCOPE PRESENTATION. By means of a sweep speed control, eight separate scope presentations are displayed successively on the scope screen. See figures 5–7 and 5–8. Sweep speeds 1, 2, 3, and 4 produce patterns which, through adjustment of the operating controls, permit the signals from a selected pair of stations to be matched. Sweep speeds 5, 6, and 7 present scope displays which can be read to indicate, in terms of microseconds, the time difference resulting from matching the signal pips. Sweep speed 8, together with the setting of the









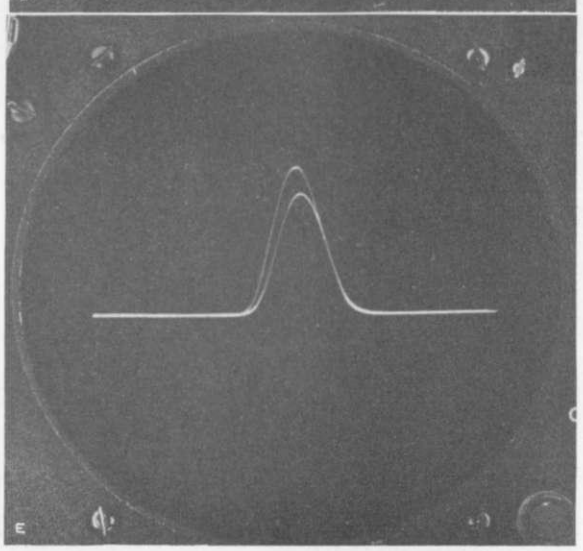


Figure 5–7.—Loran signals from a pair of stations shown on various sweep speeds:

A—Sweep speed one.

B—Sweep speed one.

C—Enlarged signals on pedestal, sweep speed two.

D—Sweep speed three.

E—Signals superimposed, sweep speed four.

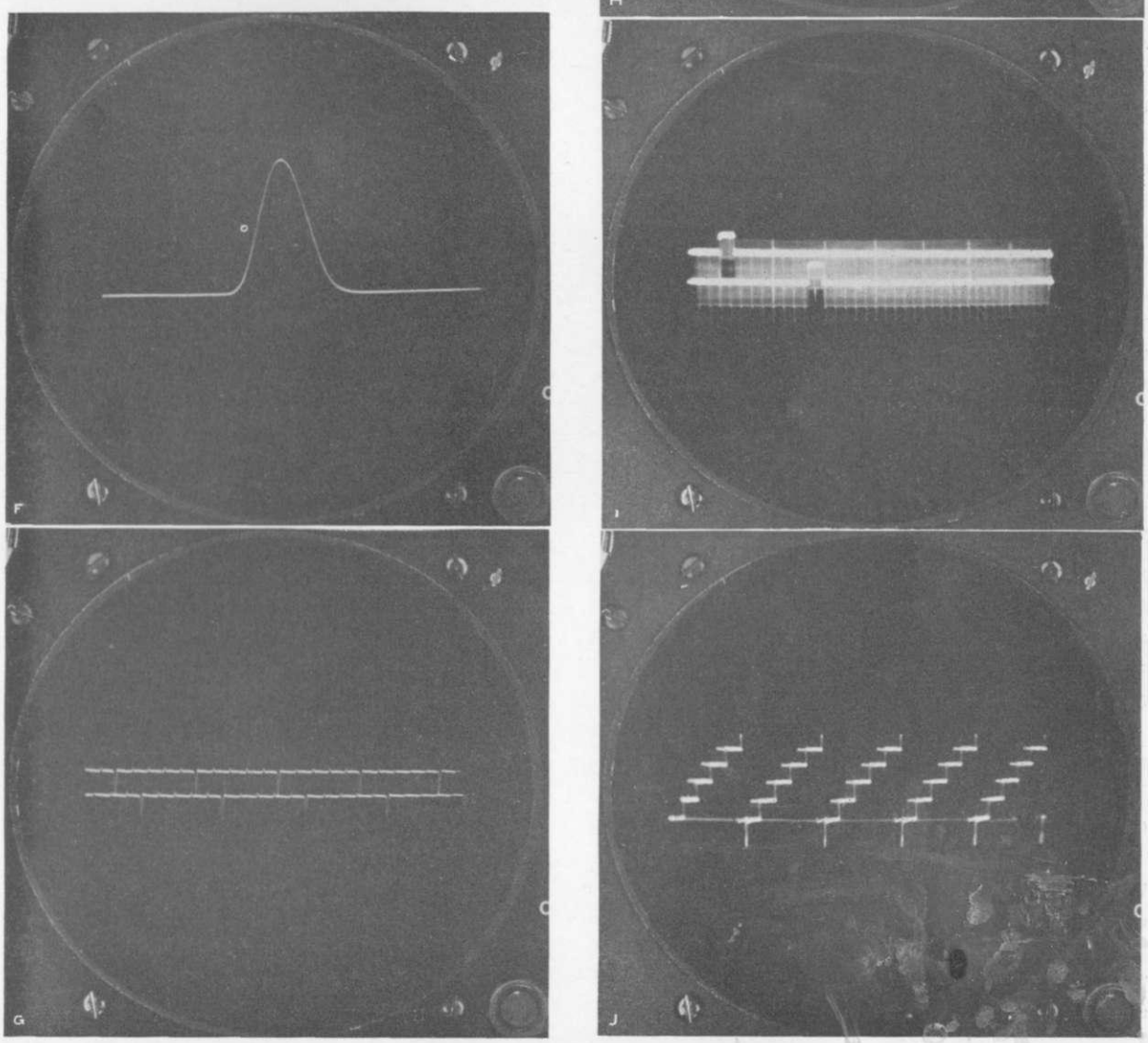


Figure 5–8.—Loran indicator counter and calibration patterns:
F—Perfect loran match, sweep speed four.
G—Sweep speed five.
H—Sweep speed six.
I—Sweep speed seven.
J—Sweep speed eight.

station selector switch, indicates the alignment, or lack of alignment, of the equipment.

1. *Sweep speed 1.*—Two horizontal traces are produced on the scope screen, each trace having in it a relatively broad square pulse, or pedestal. The top trace pedestal is stationary; the lower trace pedestal is movable along the trace. Depending upon the setting of the gain control, noise in the form of grass, and signal pips will appear on the traces. Some signal pips will drift across the traces. One pair may appear which is stationary. Use of the Left-Right switch shifts the position of the stationary pips until the top signal is on the top pedestal with the lower signal to the right of the upper one. Manipulation of the coarse and fine delay controls moves the lower pedestal along its trace to a point underneath the lower signal pip.

2. *Sweep speed 2.*—The pedestal portion of the traces, with signals, is magnified and reproduced over the entire scope screen when the equipment is adjusted to sweep speed 2. Further adjustment of the fine delay control permits the signals to be lined up, one under the other.

3. *Sweep speed 3.*—A portion of the pedestals with the signals thereon, is reproduced over the entire screen when the equipment is adjusted to sweep speed 3. Further adjustment of the fine delay control permits the signals to be more accurately aligned.

4. *Sweep speed 4.*—Here the signal and trace display is essentially the same as for sweep speed 3 except that only one trace shows, with one signal superimposed upon the other for further matching. In this position, the amplitude balance and gain controls are employed to match the signals for equal amplitude. This completes the signal-matching procedure.

5. *Sweep speed 5.*—Sweep speed 5 indicates the time difference in units of 10 microseconds. Values of time-difference less than 10 microseconds must be interpolated.

6. *Sweep speed 6.*—Sweep speed 6 indicates the time-difference in units of fifty microseconds.

7. *Sweep speed 7.*—Sweep speed 7 indicates the time-difference in units of five hundred microseconds.

The total time-difference is the sum of the readings for sweep speeds 5, 6, and 7.

Example:	*Microseconds*
Sweep speed 5	39
Sweep speed 6	400
Sweep speed 7	2000
Total	2439

This figure represents the hyperbola on the loran chart which must be selected or interpolated, for a given pair of stations, to indicate the aircraft's line of position at the time the match was finally accomplished (sweep speed 4).

A second reading can be taken from a pair of stations whose family of hyperbolas intersect those of the first pair. Advancing or retiring the lines for course made good during the interval of taking readings produces a fix whose accuracy is almost wholly dependent upon the operating skill and ability of the navigator.

III. TACTICAL EMPLOYMENT

A. Operational search and patrol missions. It may be assumed that, as a general rule, pilots and navigators are familiar with loran as a navigational aid. Too often, however, the operations officer is not aware of a loran's capabilities, particularly with reference to its ability to contribute materially, in the planning stage, to the assignment of aircraft for routine operational search and patrol missions in specific areas.

When loran is used to define search and patrol areas, the operations officer is assured that a given search or patrol mission may be executed with a higher degree of accuracy and that the designated area is covered more effectively than would be possible by the employment of other navigational methods.

Specifically, the factors which contribute to the useful tactical employment of loran by the personnel concerned with its operation are:

1. Exact knowledge of position regardless of weather.
2. Accurate rendezvous between aircraft and ships.
3. Less fuel necessary to be carried for navigational error.
4. Accurate patrol and search cruising.

B. Loran signal coverage. Whether or not loran can be employed depends upon:

1. The geographic location of loran transmitters and their day and night service ranges.

2. The strength of signal reception in a given service area. (This depends upon such factors as an over-water path between transmitter and receiver, signal attenuation due to take-off of signal over intervening land masses, and variation of signal strength with altitude.)

3. Inherent accuracy of loran lines of position for a specific area. (In areas near the base-line extension of a pair of transmitters, accuracy of time-difference readings is low.)

4. The number of pairs of stations servicing a given area and the "cut" of the resultant lines of positions.

C. Navigational uses. Loran provides a fast and accurate method of obtaining time-difference readings which can be converted directly into lines of position on the navigator's chart. Two or more lines of position are used to determine a fix. Single lines of position can be used to obtain:

1. Fixes (by crossing with celestial LOP's or radio bearings).
2. Estimated positions.
3. A constant check on the accuracy of the DR track.
4. Ground speed.
5. Drift angle (if compass deviation is known accurately).
6. Deviation on certain headings (if drift angle can be observed with the drift meter).

Furthermore, loran gives a constant indication of the aircraft's position relative to any given line of position. Courses corresponding to the bearings of the fixed loran lines can be made good with a high degree of accuracy. Winds can be determined between fixes only a few miles apart. Since drift angles can be determined, double drift (or spot) winds can be determined at night. Single lines of position can be combined with drift meter readings in such a way that spot winds may be determined without changing course of the aircraft.

D. Tactical uses. Loran can be used tactically in the following ways:

1. *Homing.*—There is a loran line of position through any geographical point within range of a pair of stations. A track coinciding with a particular line of position may be made good by flying aircraft headings that will maintain the correct time-difference reading. Thus loran lines of position may be used as lines of approach to a target. The method is simple and accurate. The time-difference reading of the line through the target is preset on the indicator and a heading is chosen which will intercept the desired line of position on one side of the target. Definite arrival and time to turn for the final approach is indicated by the observed pulses coming into coincidence. This method automatically provides the necessary correction for drift, hence it is independent of predetermination of wind.

2. *Patrol missions.*—The homing method of maintaining a track along a loran line of position may be used effectively in patrol missions or in making a systematic search of a given area. The general technique is to follow one line of position for a given distance, then to change course so as to intercept another line of position parallel to the first and separated from it by any desired distance. This back-and-forth traversal of parallel lines of position will insure that the area is completely covered.

If loran lines from another pair of stations are available, determination of wind and also the aircraft's position becomes a simple process. Once the heading to maintain track has been determined and the track plotted on the chart it is only necessary to obtain a cross line of position to get a fix. The short time required to do this makes it possible to give immediate position reports whenever they are needed.

Patrol missions may be divided into a number of specific types, each involving some particular type of flight pattern. Proper use of loran insures precise navigation and a greater effectiveness in accomplishing the purpose of the mission. Some of the various types of missions are listed below, together with some of the specific advantages of loran which are applicable to the type of mission.

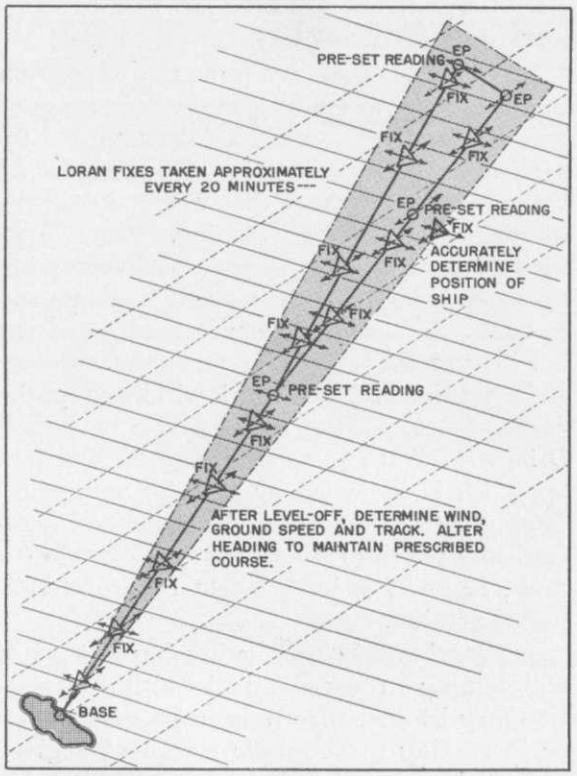


Figure 5–9.—The shaded section above represents the area of a sector search to be searched visually, by radar, or both. By utilizing loran as a planning method before flight and obtaining fixes during flight, the navigator is assured of adequately covering the assigned area. The position of observed shipping can be determined with a high degree of accuracy.

a. Sector search (see fig. 5–9) :
- (1) Maintains course easily.
- (2) Winds quickly determined.
- (3) Ability to fly under or in clouds and still obtain an accurate position at any time.
- (4) Accurate position reports possible almost immediately upon sighting vessels, other aircraft or submarines.

b. Barrier search (see fig. 5–10) :
- (1) Maintains course accurately.
- (2) When more than one aircraft is flying barrier and visibility is poor, controlled separation between aircraft can be insured.

c. Gambit (see fig. 5–11) :
- (1) Rapidity of obtaining fixes enables navigator to check position frequently, consequently the possibility of deviating from the gambit aircraft is almost nil.

d. Convoy coverage (see fig. 5–12) :
- (1) Position may be checked easily and accurately.
- (2) Accurate position reports can be reported immediately.

e. Sweeps (see fig. 5–13) :
- (1) Prescribed "overlap" and courses can be accurately flown.
- (2) "Contacts" can be reported accurately.

f. Rescue missions:
- (1) Reported position of survivors can be reached directly without necessitating a search or causing doubt as to whether or not the search aircraft is at the reported position.

g. Mine laying (see fig. 5–14) :
- (1) Accuracy and rapidity with which winds can be determined enable the navigator to compute the ballistic

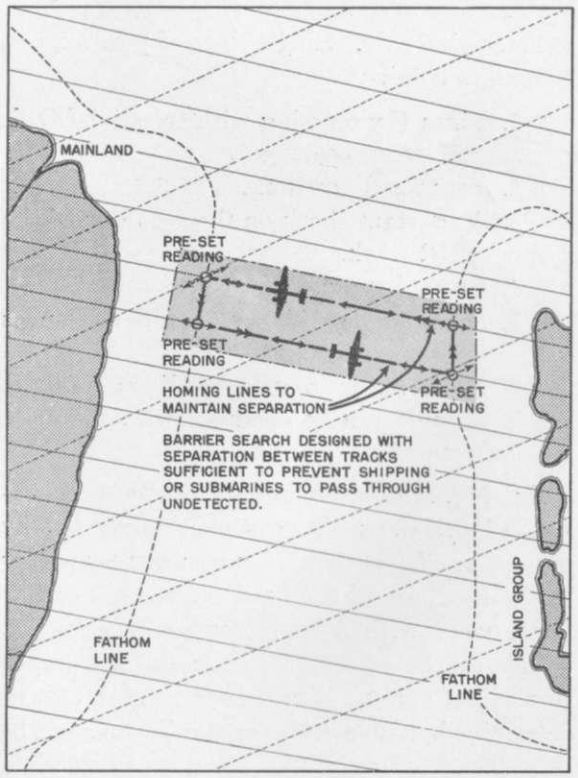


Figure 5–10.—Barrier search in a strait or between two headlands, augmented by the use of loran. Establishment of course lines at a preset turning point assures adequate and complete coverage of the assigned area.

wind and the approach heading for the mine laying run prior to the time of determining the wind by radar.

3. *Bombing mission.*—*a.* Homing method of approach simplifies all navigational problems.

b. After evasive action, position of aircraft relative to desired line of approach can be obtained almost instantly at any altitude and regardless of visibility.

c. Dangerous flak areas can be avoided easily without excessive detours. Approach to, or passage beyond, a restrictive line of position is indicated almost instantly.

d. A low-altitude approach along a line of position toward the target is possible even under conditions of poor visibility.

e. Lines of position intersecting the approach lines give very accurate ground speed checks for determining ETA at target. If intersecting lines of position pass through the target, the method used in approaching a homing line of position gives an accurate ETA at the target.

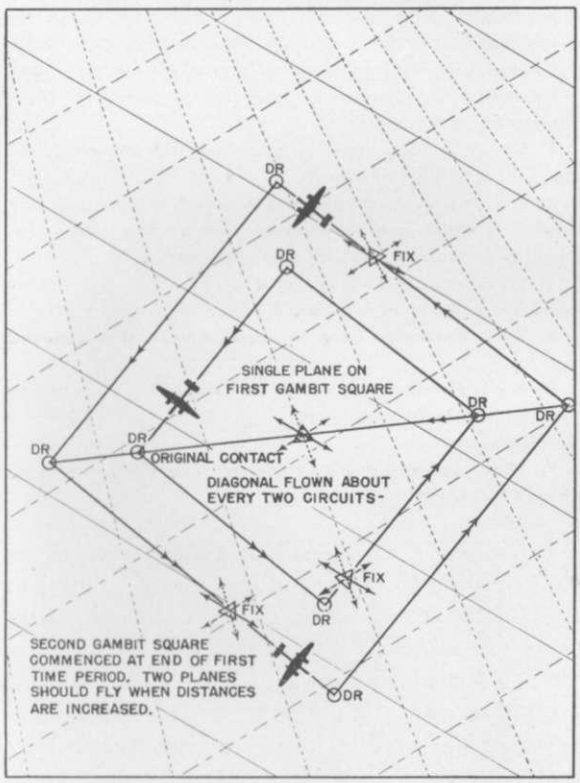

DR
FIX
SINGLE PLANE ON FIRST GAMBIT SQUARE
ORIGINAL CONTACT
DIAGONAL FLOWN ABOUT EVERY TWO CIRCUITS
SECOND GAMBIT SQUARE COMMENCED AT END OF FIRST TIME PERIOD. TWO PLANES SHOULD FLY WHEN DISTANCES ARE INCREASED.

Figure 5–11.—When a detected submarine submerges the effectiveness of a gambit search diminishes if the square is off center; that is, not equidistant from the original point of contact. Loran can be employed to accurately locate the point of submergence in terms of latitude and longitude and to insure that the actual track of the gambit corresponds to the predicted courses of the square.

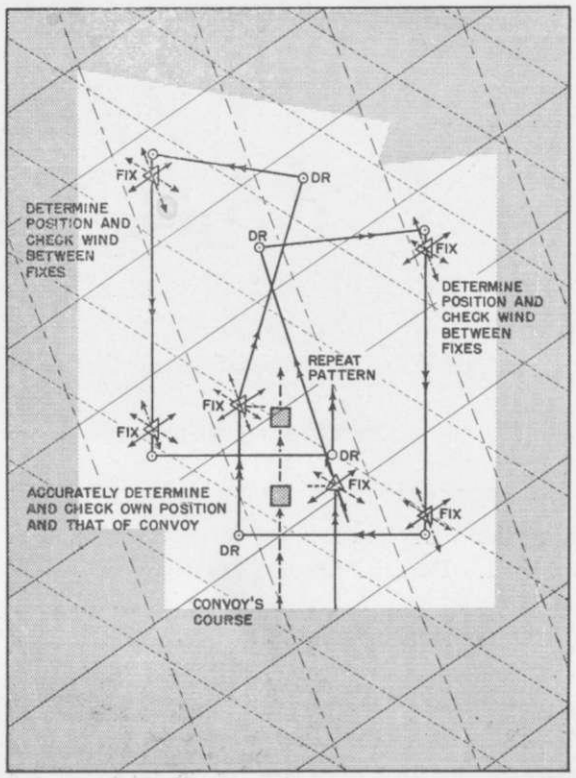

DETERMINE POSITION AND CHECK WIND BETWEEN FIXES
DETERMINE POSITION AND CHECK WIND BETWEEN FIXES
REPEAT PATTERN
ACCURATELY DETERMINE AND CHECK OWN POSITION AND THAT OF CONVOY
CONVOY'S COURSE
FIX
DR

Figure 5–12.—In order to maintain the predetermined pattern or plan of air convoy escort, loran lines of position can be employed to obtain fixes for determining wind, course, speed, and the turning point required for adequate air coverage.

4. *Long range navigation.*—*a.* On long overwater flights, course may be maintained accurately.

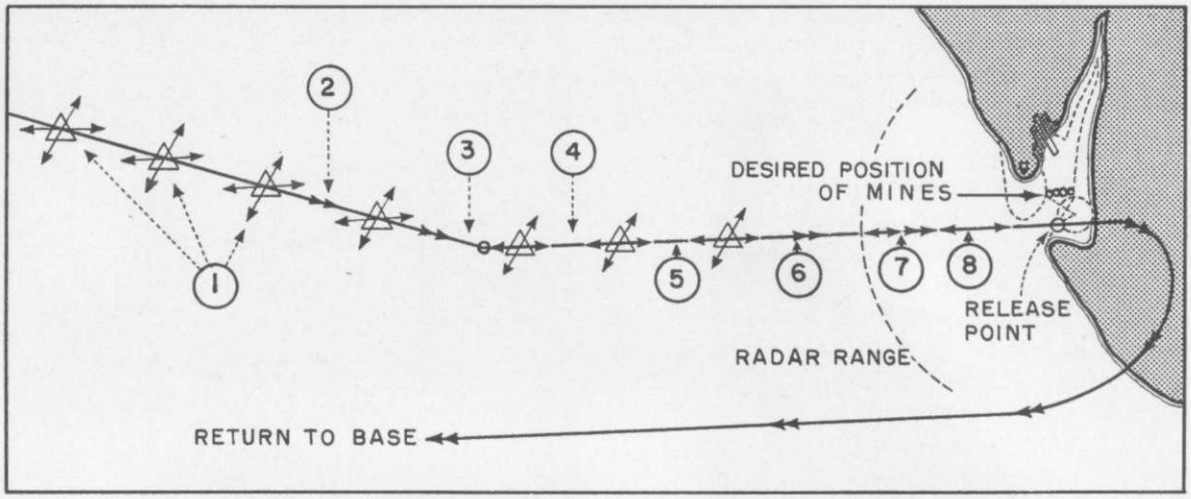
b. Immediate indication is given of any changes in wind or drift.

c. Winds can be determined quickly after passing through a front, or after a change of altitude.

d. With adequate coverage, it is always possible to home to any desired geographical point.

e. Flights can be planned and made without large deviations from course due to unexpected changes in winds or weather.

5. *Traffic guidance.*—Aerial traffic over congested routes can be controlled by assigning



altitudes and loran lines of position to each aircraft. Parallel lines of position are chosen so as to maintain separation of aircraft, even under instrument conditions.

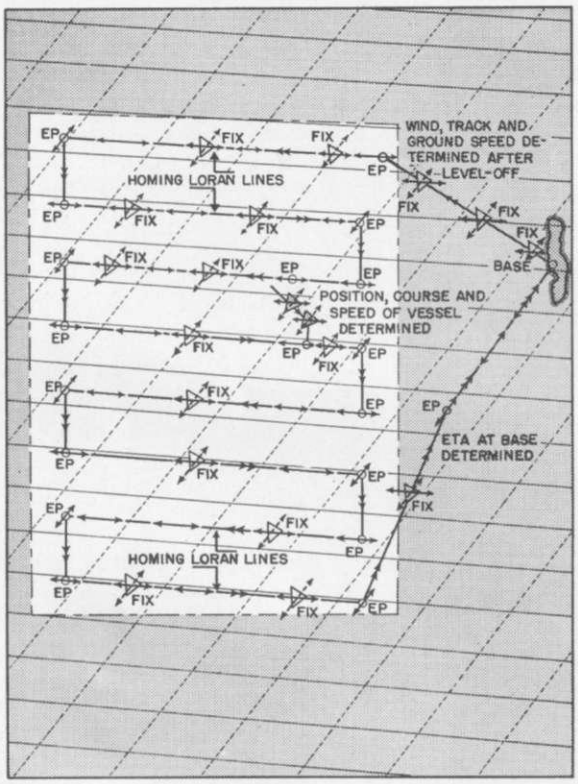


Figure 5–13.—This figure illustrates how the loran lines of position represented above by the dotted and solid parallel lines can be employed to determine the estimated positions and fixes in executing a patrol sweep of a designated area.

Figure 5–14.—Mine laying from high altitudes requires the use of drogue mines, which in turn require the determination of the ballistic wind. The principal advantage of loran in mine laying are that wind and flight altitude and the heading to make good the desired course for laying the mines can be determined before coming within radar range. Consequently, during the last minutes of the run there need be only minor alterations of heading to correct for slight errors in wind or course.

1. Navigator takes series of loran fixes and determines accurate wind at flight altitude.

2. Knowing wind, altitude, and airspeed, find the necessary heading to make good the approach course. This involves solution of the ballistic problem by the navigator.

3. When loran homing approach can be made, preset reading and complete turn as pulses are lined up.

4. While homing on loran lop, check wind-drift and ground speed.

5. Revise ETA to release point.

6. Recheck ballistic problem.

7. Navigate by radar.

8. Wind and track checked by radar. Only slight alterations of heading should be necessary.

6. *Traffic control.*—The same principle as that applied to traffic guidance may be used to control congested traffic over an airport. Aircraft are assigned altitudes and lines of position so that each flies a definite flight pattern around or over the airport. Separation of aircraft at the same altitude is accomplished by assigning each a separate time difference reading for each course around the area. Radio approach channels may be guarded by designating restrictive lines of position for each channel.

For coverage of loran stations, see the Loran Chartlets contained in the appendix.

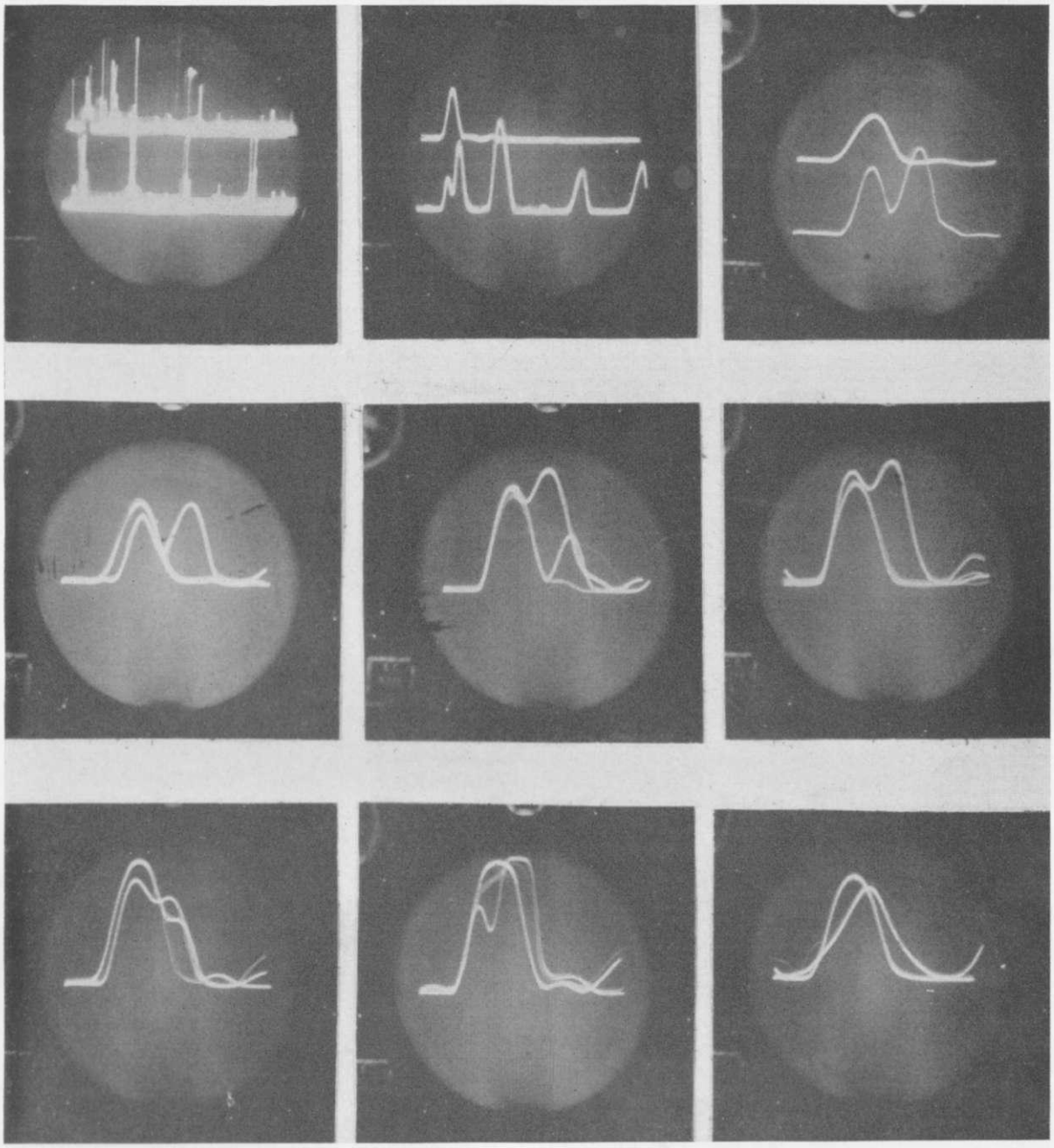


Figure 5–15.—Above is shown a group of frames taken from a motion picture showing the characteristics of loran sky waves. At the top, reading from left to right, is shown the sky-wave signals received on sweep speeds 1, 2, and 3. The middle and bottom row of photographs show the successively changing shapes of the sky waves caused by splitting as a match, on sweep speed 4, is attempted.

PART SIX

RADIO ALTIMETERS

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AN/APN–1

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PART SIX

RADIO ALTIMETERS

THEORY AND PRINCIPLES OF OPERATION

I. GENERAL

The radio altimeter is an electronic aircraft instrument designed to indicate an aircraft's absolute altitude above the surface of the earth from zero to 4,000 feet.

The time required for a special radio signal to travel from the aircraft to the earth below and be reflected back to the aircraft is measured by the electronic equipment. Since the elapsed time is directly proportional to the distance traveled, the equipment converts this measurement into a direct altitude indication.

A transmitter and receiver are the main components of the radio altimeter. They generate and receive all the signals required for altitude measuring.

The altitude indicator shows the absolute altitude of the aircraft directly in feet, by needle deflection. Another altitude indication is provided by a limit switch and limit lights. By watching these limit lights, the pilot can fly at a predetermined, fixed altitude. This is done by setting the limit switch to the altitude that it is desired to maintain. Any altitude between 50 and 300 feet—at 25-foot intervals can be selected (AN/APN–1 has additional range settings of 500 and 3,000 feet, at 250-foot intervals). As long as the aircraft's altitude is within 10 feet of the limit switch setting, a white indicator light glows (100 feet for 400- to 4,000-foot range). If the aircraft rises more than 10 feet above the limit switch setting, a green light glows (100 feet for 400- to 4,000-foot range). If the aircraft falls more than 10 feet below the limit switch setting, a red light glows (100 feet for 400- to 4,000 foot range).

II. PRINCIPLES OF OPERATION

An electronic altimeter system, shown diagrammatically in figure 6–1, comprises the following elements:

1. A transmitter unit:
   F–M transmitter and audio oscillator.
2. A receiving unit:
   Balanced detector and audio amplifier.
3. An indicator unit:
   Indicator counter.
   Indicator amplifier.
   Altitude meter.
   Limit counter.
   Limit amplifier and relay.
   Limit switch.
   Limit lights.
4. Transmitting and receiving antennas.

NOTE.—Excepting for the difference in altitude ranges which they indicate AN/ARN–1, 0 to 400 feet; (AN/APN–1, 0 to 400 and 400 to 4,000 feet), the two electronic altimeter equipments now in use employ the same fundamental principles of operation. (Fig. 6–1.)

Referring to the block diagram, the audio oscillator generates an audio frequency signal of 120 cycles per second which is fed into the transmitter.

The transmitter generates a radio signal of constant amplitude. The frequency of the transmitter signal is controlled by the audio oscillator signal so that, 120 times per second, its frequency is varied from 420 to 460 megacycles, and back to 420 megacycles continuously on the 0- 400-foot range (and from 443 to 447 megacycles and back, on the 400- to 4,000-foot range). Because the transmitter signal is constant in amplitude but varying in frequency, it is said to be "frequency modulated." This frequency modulated signal is fed to both the balanced detector and the transmitting antenna.

Each of the antennas consist of a dipole, usually mounted under the wing or fuselage. The transmitting antenna radiates energy in all directions broadside to the dipole, but very little from its ends. Since the wing or fuselage acts as a reflector, most of the energy is radiated downward, and, on striking the earth, is reflected back to the aircraft where it is received

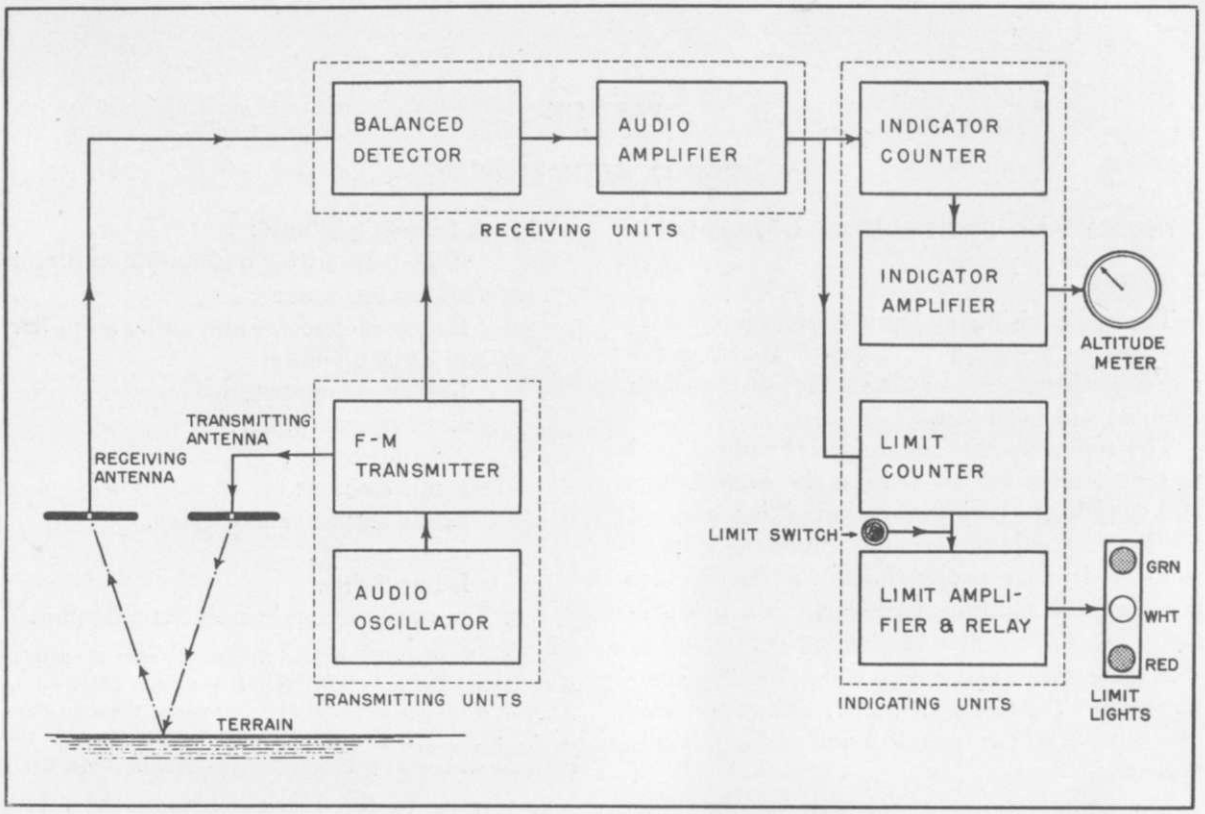


Figure 6–1.—This block diagram of the AN/APN–1 series of electronic altimeter equipments illustrates generally the function of the system. The transmitting units furnish a frequency modulated signal variable over a specific band to the transmitting antenna and to the receiver. The signal is directed downward to the terrain where it is reflected back to the receiving antenna and to the receiver. Since a measurable period of time has been consumed in the travel of the signal, its frequency will differ from the signal frequency then being generated. This difference frequency will vary in accordance with time or altitude. The receiving section converts the difference frequency into terms of electric current whose values are proportional to altitude. The indicating sections register the altitude in terms of feet on the meter and in terms of altitude limits on the limit lights.

by a receiving antenna. The time taken for the energy to travel down to earth and back again is directly proportional to the absolute altitude of the airplane.

From the receiving antenna, the energy travels to the balanced-detector, which at the same time, is receiving signals direct from the transmitter. The transmitter is constantly changing in frequency. At one instant of time, it sends a signal of one frequency to the transmitting antenna. By the time the signal reaches the ground and is reflected back to the aircraft, a definite time has elapsed, and the transmitter is now generating a new frequency. The higher the aircraft is from the ground, the longer it takes for the signal to travel down to the earth and back, and the greater difference there is between the frequencies of the two signals being fed to the receiver.

The balanced detector mixes the two signals—the one coming directly from the transmitter and the one reflected from the earth—and produces a third signal, equal to the frequency difference of the two. This difference frequency is amplified by two audio amplifier stages.

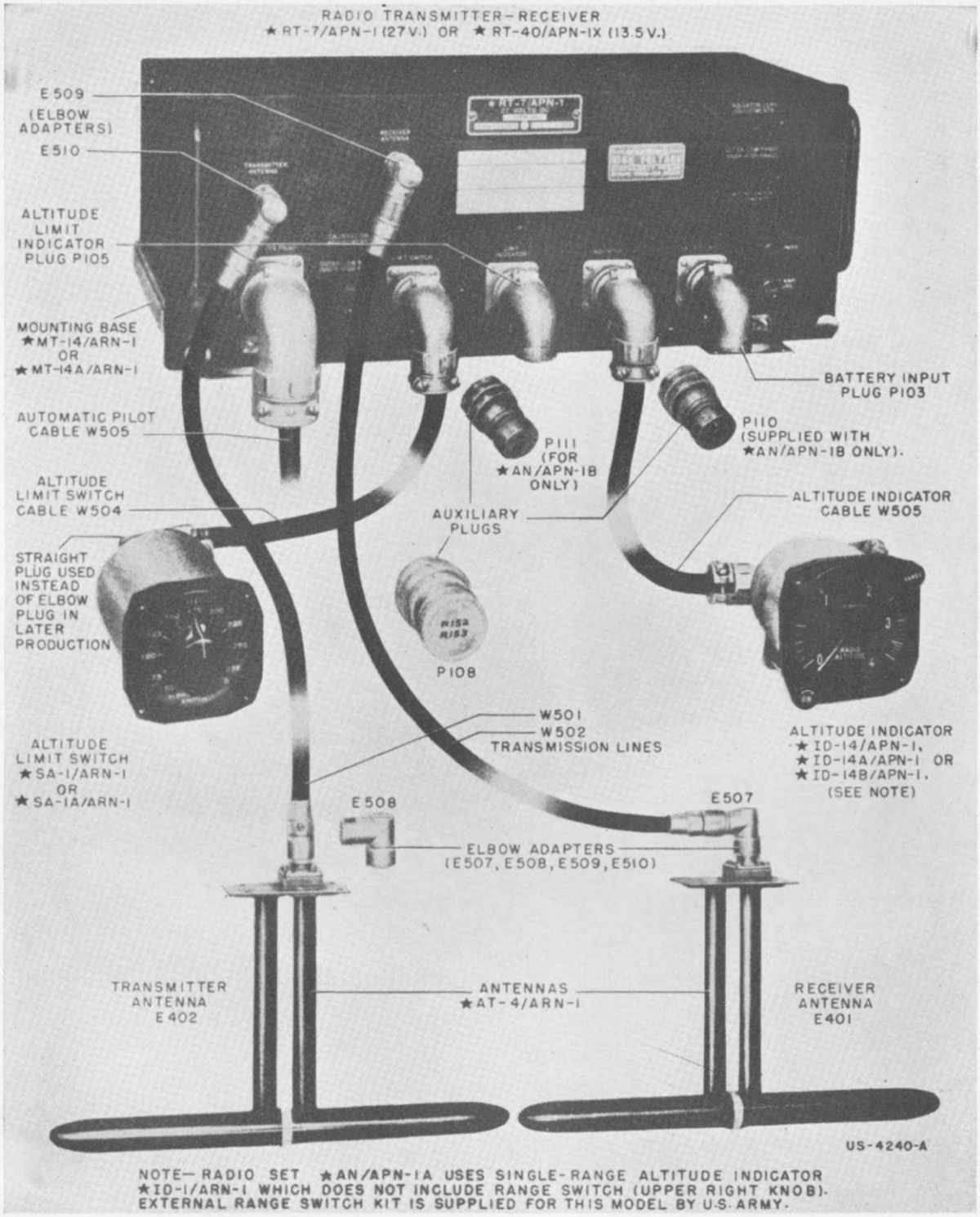
From the audio amplifier, the signal, sinusoidal in wave form, goes to the limiter, which also amplifies and, at the same time, clips off both the top and bottom so as to produce a square wave. The reason for amplifying, then clipping, the difference frequency is to insure that the amplitude of this square wave is always the same, regardless of the strength of the re-

flected signal. Thus, changes in altitude will vary the frequency but not the amplitude of the square wave.

From the limiter, the square wave goes to two circuits—the indicator counter and the limit counter. These counter circuits produce currents proportional to the frequency of the square wave fed to them, and thus proportional to the altitude of the airplane.

Current from the indicator counter circuit is fed to a milliampmeter, which is calibrated in feet, to indicate the absolute altitude of the airplane. Current from the limit counter circuits controls two relays which turn the limit lights on and off as the altitude varies beyond the limits set by the setting of the limit switch.

When used in conjunction with an automatic pilot system, the radio altimeter can be set for automatic operation, causing the altimeter to assume flight control of the aircraft within limits defined by the presetting of the limit switch.



NOTE— RADIO SET ★AN/APN-1A USES SINGLE-RANGE ALTITUDE INDICATOR ★ID-1/ARN-1 WHICH DOES NOT INCLUDE RANGE SWITCH (UPPER RIGHT KNOB). EXTERNAL RANGE SWITCH KIT IS SUPPLIED FOR THIS MODEL BY U.S. ARMY.

AN/APN-1

AN/APN–1

NOTE.—AN/APN–1 is a two-range (0–400; 400–4,000 feet) radio altimeter whose source of supply is 27 volts d. c. AN/APN–1A is similar in all respects to AN/APN–1 excepting that it uses a single range indicator which can be adapted for dual range indication by the addition of an appropriate external switching device. AN/APN–1B is a two-range radio altimeter intended for special duty in connection with other equipments. AN/APN–1X is similar to AN/APN–1 in all respects excepting that its source of supply is 13.5 volts d. c.

I. FUNCTION

A. PRIMARY PURPOSE. AN/APN–1 is an aircraft radio altimeter which will indicate the absolute altitude of an aircraft between the limits of 0 to 4,000 feet, in two ranges: 0 to 400 feet, and 400 to 4,000 feet.

B. SECONDARY USES. AN/APN–1, in addition to indicating the altitude of an aircraft, will also operate to furnish visual indication of an aircraft's deviation from, or maintenance of, a preset value of altitude.

By suitable connection to an automatic pilot system, the AN/APN–1 may be used to control the altitude of flight with reference to any preset altitude, as determined by the setting of an altitude limit switch, in steps of 25 feet from 50 to 300 feet inclusive, and in steps of 250 feet from 500 to 3,000 feet inclusive.

II. DESCRIPTION

A. MAIN COMPONENTS. The AN/APN–1 consists of the following units:

1. Radio transmitter-receiver.
2. Two dipole antennas.
3. Altitude indicator meter.
4. A bank of three altitude limit lights.
5. An altitude limit switch.
6. Connecting cables.

B. MODE OF OPERATION. 1. *Altitude calibrated current meter.*—The AN/APN–1 series of radio altimeters employ a frequency-modulated transmitter to generate a constantly changing radio frequency wave (constant in amplitude) which is directed toward the earth by a transmitting antenna. A reflected wave returns from the earth, is picked up by a receiving antenna and passed along to the receiver section of the equipment. At any one instant of time there will be a difference in frequency between the reflected wave and the transmitted wave. This frequency difference will be proportional to the time (distance) required for the wave to travel from the aircraft, to the earth, and back again to the aircraft.

Suitable circuits in the receiver convert this frequency difference into values of current whose strength is proportional to altitude. The current indicating meter is calibrated in terms of feet of altitude.

2. *Altitude limit lights.*—An additional indication of levels of altitude is obtained through the use of current-relay-operated altitude limit lights. When an altitude limit switch is set for any given altitude within the range of the equipment (in steps of 25 feet for the low range and 250 feet for the high range), relay switches, affected by changing values of current, will operate to cause indicator lights to glow.

If the aircraft maintains the preset limits of altitude, a white light glows. If the aircraft's altitude rises above the preset limit, a green light glows. If the aircraft's altitude falls below the preset limit, a red light glows. See figure 6–2.

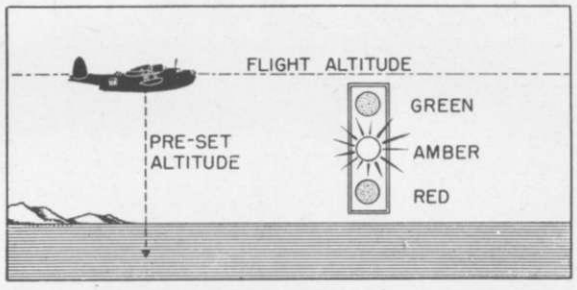


Figure 6–2.—So long as the aircraft maintains an altitude equal to the value preset by the altitude limit switch, an amber light will glow. If the aircraft deviates more than 25 feet from this preset altitude a red light glows for decreased altitude and a green light for increased altitude.

APPENDIX

TYPE EQUIPMENT	PULSE CHARACTERISTICS				RANGE		
	FREQ. IN MC.	PULSE LENGTH	PULSE RATE	PEAK PWR-KW	RANGE SETTINGS (MI.)	MIN. EFFECT. RANGE	RANGE ACCURACY
ASB	515	2 MICRO-SECONDS	400	4 - 6	2 7 28 70	400 YARDS	± 10%
ASG ASG-1	3300	1 - SEARCH 2 - BEACON	650 - SEARCH 325 - BEACON	30 - 50	5 20 50 90	400 YARDS	±7%
AN/APS-2F	3300 (3256 ON BEACON)	1 - SEARCH 2 - BEACON	650 - SEARCH 325 - BEACON	30 - 50	A (5) B (20) C (50) D (100)	400 YARDS	±7%
AN/APS-15	9375 (9335 ON BEACON)	.5 [5 MI. 20 " 50 " 1 - 100 " 2 - BEACON	1000 [5 MI. 20 " 50 " 650 - 100 " 325 BEACON	40 - 50	5 20 50 100	200 YARDS	±1 TO 7%
ASD	9375 ±85	.5 [4 MI. 40 " 2 ON 100 MI. AND BEACON	1300 [4 MI. 40 " 325 ON 100 MI. AND BEACON	10 - 20	4 40 100	200 YARDS	±10%
AN/APS-3	9375 ±30	.5 [4 MI. 10 " 1 [40 " 80 " 2 - BEACON	1500 [4 MI. 10 " 750 [40 " 80 " 375 - BEACON	15 - 20	4 10 40 80 120 - BEACON	200 YARDS	±7%
AN/APS-4	9375 (9335 ON BEACON)	.6 ON SEARCH 2.1 ON BEACON	1000 [4 MI. 20 " 50 " 600 - 100 " 350 - BEACON	40 - 50	4 20 50 100	100 YARDS	±5%
AN/APS-6A	9375 (9335 ON BEACON)	2 [SEARCH BEACON .5 [INTERCEPT GUN AIM	500 - SEARCH 2000 [INTER-CEPT & GUN AIM	15 - 50	1 5 25 65 BEACON - 100	120 YARDS	±10% SEARCH ±5% INTERCEPT ±25 YARDS ON GUN AIM

CONFIDENTIAL

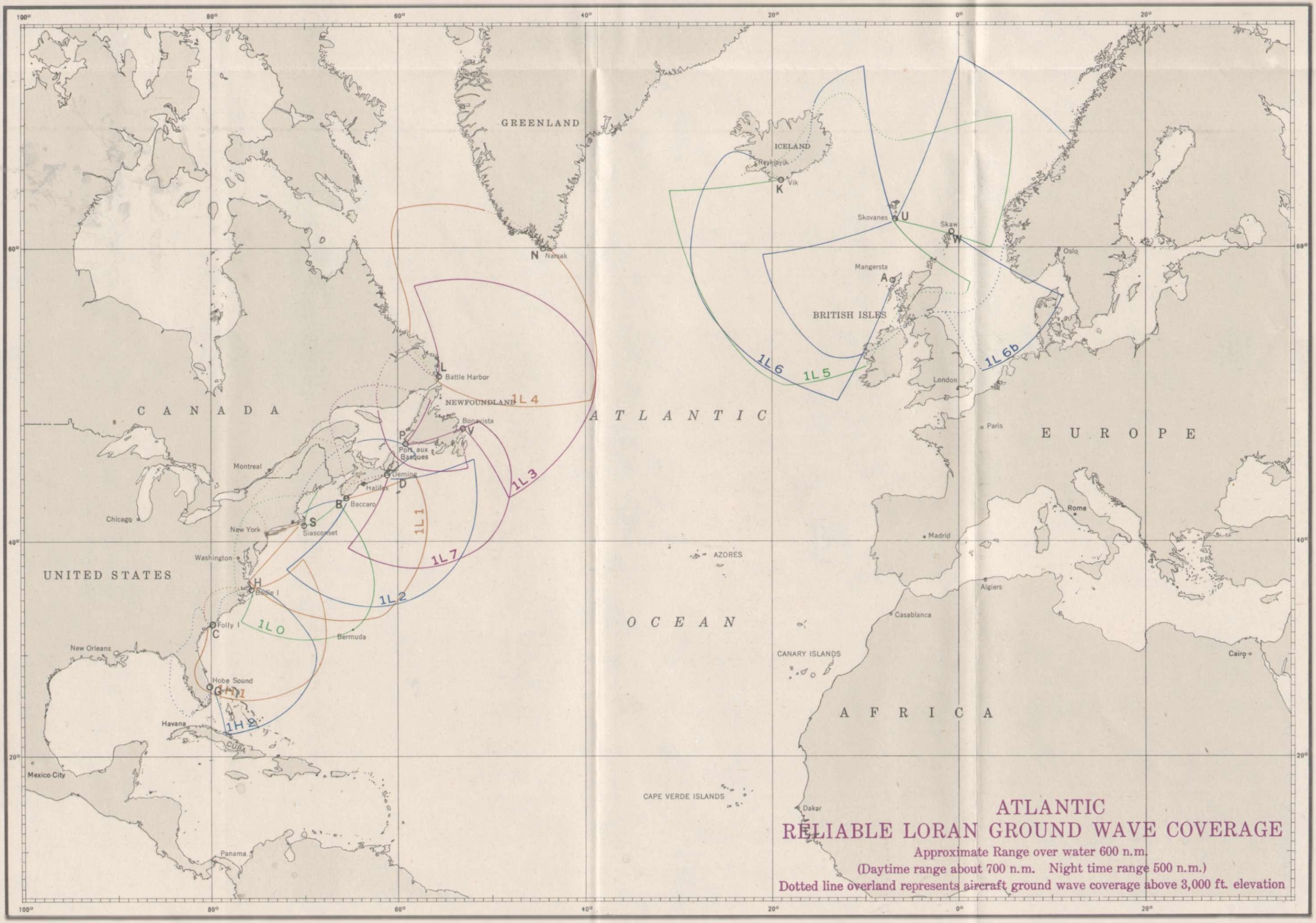
ANTENNA CHARACTERISTICS					CATHODE-RAY TUBE INDICATOR		MAX. OPRTG ALT.-FT.
TYPE	BEAM	AZIMUTH SCAN	ELEVATION SCAN	ANGLE OF ACCURACY	TYPE	DISPLAY	
YAGI	40°	010° TO 090° 350° TO 270° MOVED BY MANUAL CONTROL	-25° TO -5° ON SEARCH -35° TO ± 15° ON HOMING	+2° TO -5° (HOMING)	5 INCH	L - SCAN	20,000
30 - INCH PARABOLOID	9°	360° HI - 24 RPM LO - 12 RPM	-20° TO +20°	±3°	5 - INCH 2 - INCH	PPI - PRI A - SCOPE	15,000
29 - INCH PARABOLOID	8.7°	360° HI - 24 RPM LO - 12 RPM	-20° TO +20°	±3°	5 - INCH 2 - INCH	PPI - PRI A - SCOPE	15,000
29 - INCH PARABOLOID	3°	360° HI - 24 RPM LO - 12 RPM	-20° TO +20°	±1.5°	5 - INCH 2 - INCH	PPI - PRI A - SCOPE	36,000
18 - INCH PARABOLOID	5°	140°	-12 TO +7°	±3°	5 - INCH (2)	B - SCAN	20,000
18 - INCH PARABOLOID	5° CONE (APPROX.)	150° 35 RPM	-8° TO +6°	±3°	5 - INCH (2)	B - SCAN	20,000
14 - INCH PARABOLOID	6° CONE	SEARCH - 150° 30 SCANS/MIN. INTERCEPT - 60 SCANS/MIN.	-30° TO +10° ON SEARCH -30° TO +30° ON INTERCEPT	±3°	3 - INCH (2)	B - SCAN ON SEARCH H - SCAN ON INTERCEPT	30,000
17 - INCH PARABOLOID	7°	120° CONE INTERCEPT AND SEARCH. 15° CONE - GUN AIM.	±60°	±3°	3 - INCH	B - SCAN ON SEARCH O - SCAN ON INTERCEPT G - SCAN ON GUN AIM	30,000

ELECTRONIC BOMBING EQUIPMENTS

EQUIPMENT	PARENT EQUIPMENT	METHOD OF BOMB RELEASE	ALTITUDE LIMITS		CLOSING SPEED	ACCURACY
			MINIMUM	MAXIMUM		
AN/APA-16	ASB AN/APS-3 AN/APS-4	AUTOMATIC	50 FEET	500 FEET	50-400 KNOTS	PARENT RADARS ASB & AN/APS-3. MEAN RADIAL ERROR 30-35 FEET (TESTS, NAS, PATUXENT RIVER)
AN/APQ-5B	AN/APS-3 AN/APS-2 AN/APS-15 APS-15A,-15B	AUTOMATIC	65 FEET	2,000 FEET WITH AUTOMATIC COMPUTER; 50,000 FT. APPROX. WITH USE OF CHARTS.	100 - 400 M.P.H.	*AT AVERAGE OF 160 M.P.H.—* ALTITUDE 500 FT. | ERROR® 75 FT. " 1000 " | " 110 " " 1500 " | " 125 " " 2000 " | " 140 " ® PROB. ERR. "X" BAND, "S" BAND ADD 50%
AN/APA-5 *(REPLACES AN/APQ-5B)*	AN/APS-3 AN/APS-15 APS-15A,-15B AN/APS-30 SERIES	AUTOMATIC	0 FEET	35,000 FEET APPROX.	0 - 400 M.P.H.	TESTS UNDERWAY INDICATE MUCH MORE ACCURATE THAN AN/APQ-5B
AN/APG-4	AYD-- AN/ARN-1 AN/APN-1	AUTOMATIC	40 FEET	400 FEET	130 - 350 KNOTS	(TESTS NAMC & PATUXENT RIVER) SPEED RANGE 60-180 KNOTS ALT. RANGE 100-200 FEET AVERAGE RANGE ERROR -- ALL TESTS ——— 34 FEET AVERAGE MPI ——— +22 FEET
AN/APG-17 *(REPLACES AN/APG-4)*	AN/APN-1	AUTOMATIC	40 FEET	400 FEET	130 - 350 KNOTS	NO TACTICAL EVALUATION TO 1 MAY 1945.

Note: Fourteen Loran chartlets follow this page.

U. S. GOVERNMENT PRINTING OFFICE: 1946



ATLANTIC
RELIABLE LORAN GROUND WAVE COVERAGE

Approximate Range over water 600 n.m.
(Daytime range about 700 n.m. Night time range 500 n.m.)
Dotted line overland represents aircraft ground wave coverage above 3,000 ft. elevation

ATLANTIC
RELIABLE LORAN SKY WAVE COVERAGE

Approximate range over water from 300 n. m. to 1,300 n. m.

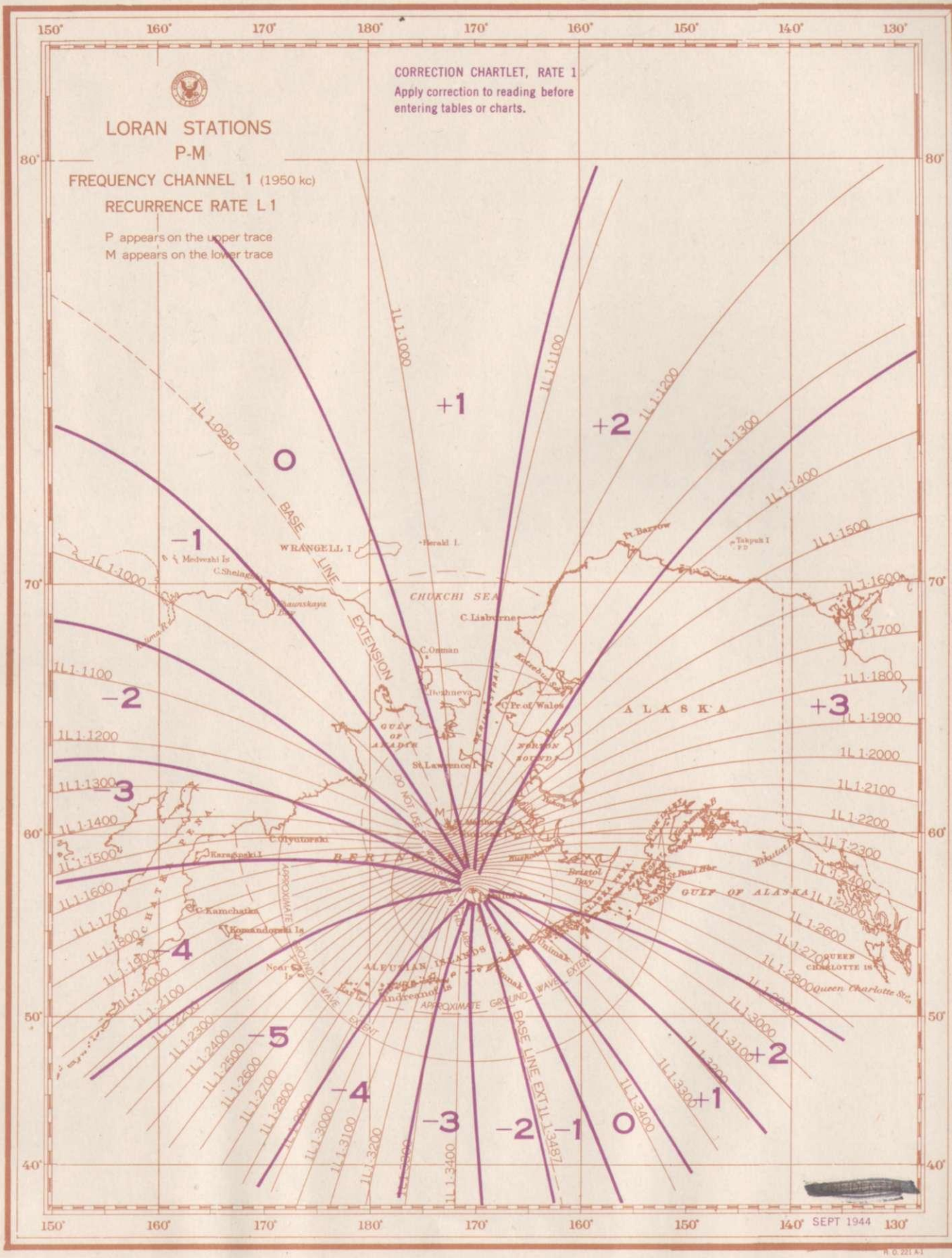
PACIFIC
RELIABLE LORAN GROUND WAVE COVERAGE

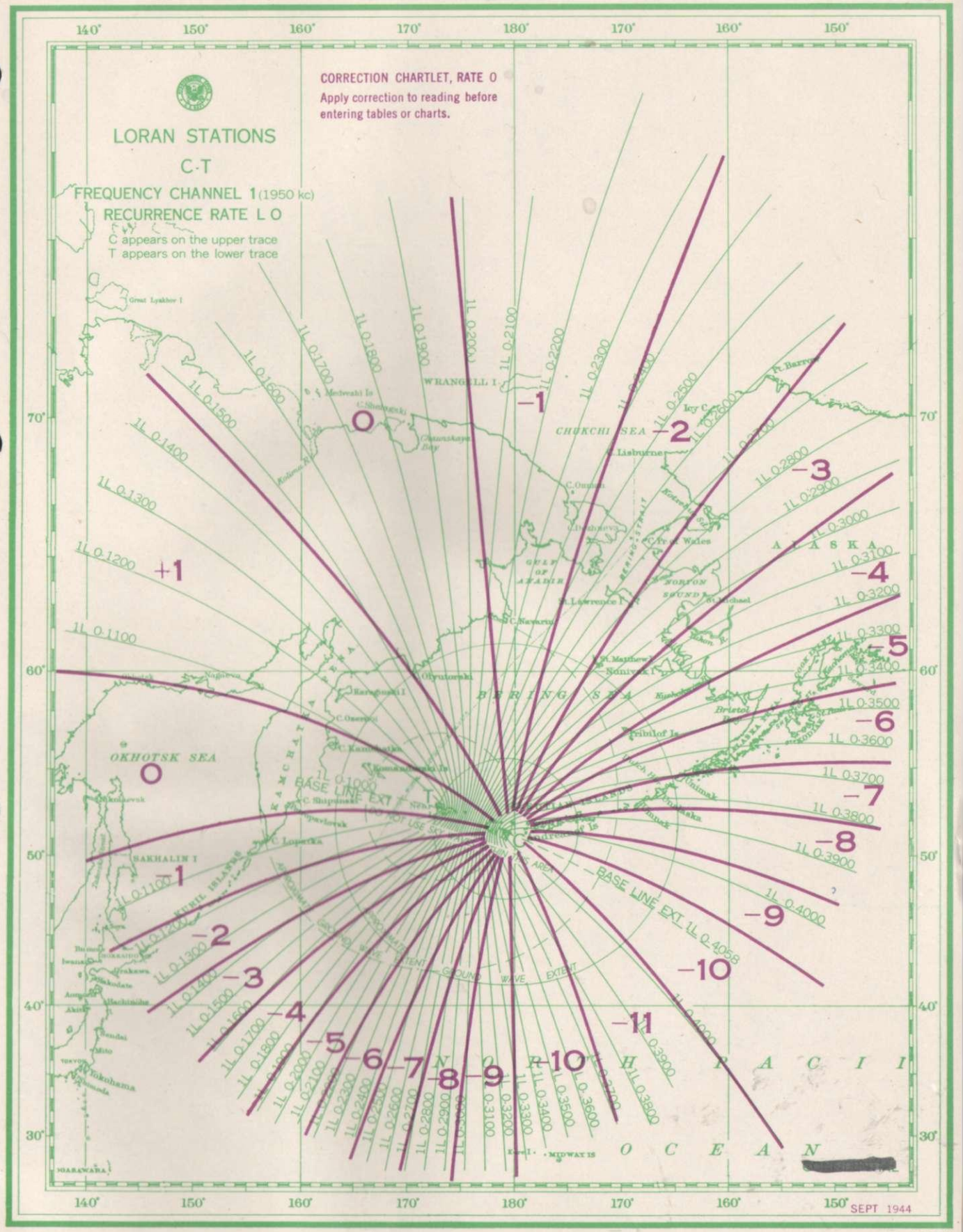
Approximate range over water 600 n.m.
(Daytime range about 700 n.m. Night time range about 500 n.m.)

ALASKA
CANADA
UNITED STATES
MEXICO
ASIA
CHINA
JAPAN
PACIFIC OCEAN
AUSTRALIA
INDIAN OCEAN
NEW ZEALAND
PHILIPPINE ISLANDS
ALEUTIAN ISLANDS
HAWAIIAN ISLANDS
MARIANAS
CAROLINE IS
MARSHALL IS
PHOENIX IS
SOLOMON IS
NEW HEBRIDES
FIJI IS
NEW GUINEA
SUMATRA
BORNEO
JAVA
Nome
St Matthew
St Paul I
Okhotsk
Attu I
Amchitka I
Umnak
Vancouver I
Seattle
Chicago
San Francisco
Washington
New Orleans
Panama
Lima
Vladivostok
Pei-p'ing
Tokyo
Shang-hai
Hong Kong
Manila
Marcus I
Wake I
Frigate East I
Niihau
Hawaii
Guam
Saipan I
Ulithi Is
Peleliu (Palau)
Pulo Anna
Morotai
Kwajalein
Majuro I
Makin I
Baker I
Gardner I
Atafu I
Bathurst I
Sir Graham Moore
Champagny I
Broome
Sydney
Melbourne
Auckland
1L 0
1L 1
1L 2
2L 0
2L 1
2L 2
2L 3
2L 4
2L 5
2H 5
4H 2
4H 3
4H 4
4H 6
4H 7
M
P
T
C
U
G
Q
J
S
V
H
K
D
L
E
R
F
N
W
A

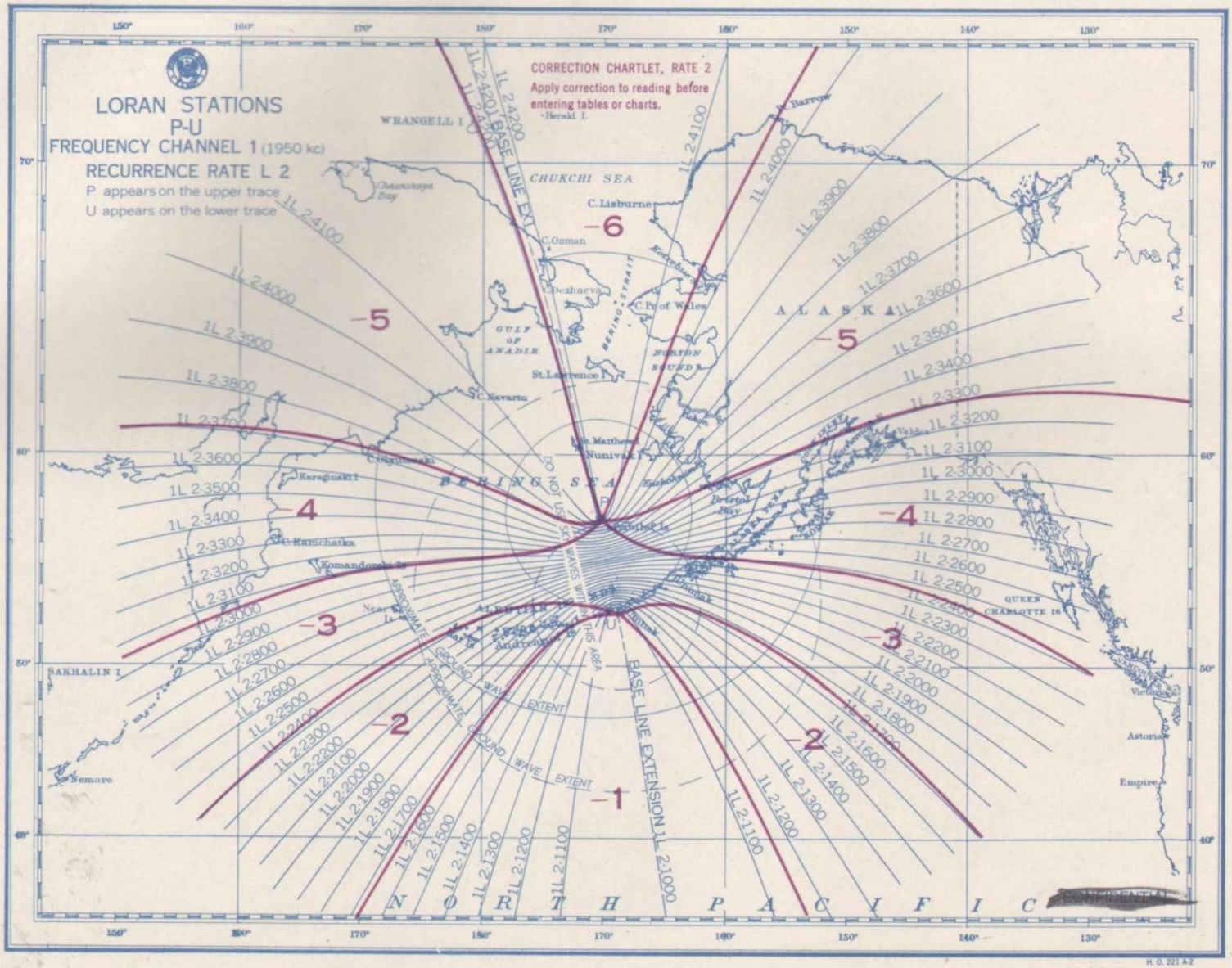
PACIFIC
RELIABLE LORAN SKY WAVE COVERAGE

Approximate range over water from 300 n. m. to 1,200 n. m.


CORRECTION CHARTLET, RATE 1
Apply correction to reading before entering tables or charts.
LORAN STATIONS
P-M
FREQUENCY CHANNEL 1 (1950 kc)
RECURRENCE RATE L 1
P appears on the upper trace
M appears on the lower trace
BASE LINE EXTENSION
APPROXIMATE GROUND WAVE
BASE LINE EXTN
APPROXIMATE GROUND WAVE EXTN
DO NOT USE
CHUKCHI SEA
ALASKA
BERING SEA
GULF OF ALASKA
ALEUTIAN ISLANDS
Wrangell I.
Herald I.
Pt. Barrow
Tasiuk I
C. Lisburne
C. Onman
Pr. of Wales
St. Lawrence I.
C. Olyutorski
C. Kamchatka
Komandorski Is.
Near Is.
Andreanof Is.
Bristol Bay
Kodiak I.
Cook Inlet
Prince William Sound
Juneau
Sitka
Queen Charlotte Is.
Queen Charlotte Str.
1L1·1000
1L1·1100
1L1·1200
1L1·1300
1L1·1400
1L1·1500
1L1·1600
1L1·1700
1L1·1800
1L1·1900
1L1·2000
1L1·2100
1L1·2200
1L1·2300
1L1·2400
1L1·2500
1L1·2600
1L1·2700
1L1·2800
1L1·2900
1L1·3000
1L1·3100
1L1·3200
1L1·3300
1L1·3400
1L1·3487
1L1·0950
+1
+2
+3
0
−1
−2
−3
−4
−5
SEPT 1944


CORRECTION CHARTLET, RATE O
Apply correction to reading before entering tables or charts.
LORAN STATIONS
C-T
FREQUENCY CHANNEL 1 (1950 kc)
RECURRENCE RATE L O
C appears on the upper trace
T appears on the lower trace
140° 150° 160° 170° 180° 170° 160° 150°
70° 60° 50° 40° 30°
WRANGELL I.
CHUKCHI SEA
ALASKA
BERING SEA
OKHOTSK SEA
SAKHALIN I
HONSHU
PACIFIC OCEAN
BASE LINE EXT.
GROUND WAVE EXTENT
SEPT 1944
H. O. 221 A-0

~~CONFIDENTIAL~~



H. O. 221 A-2

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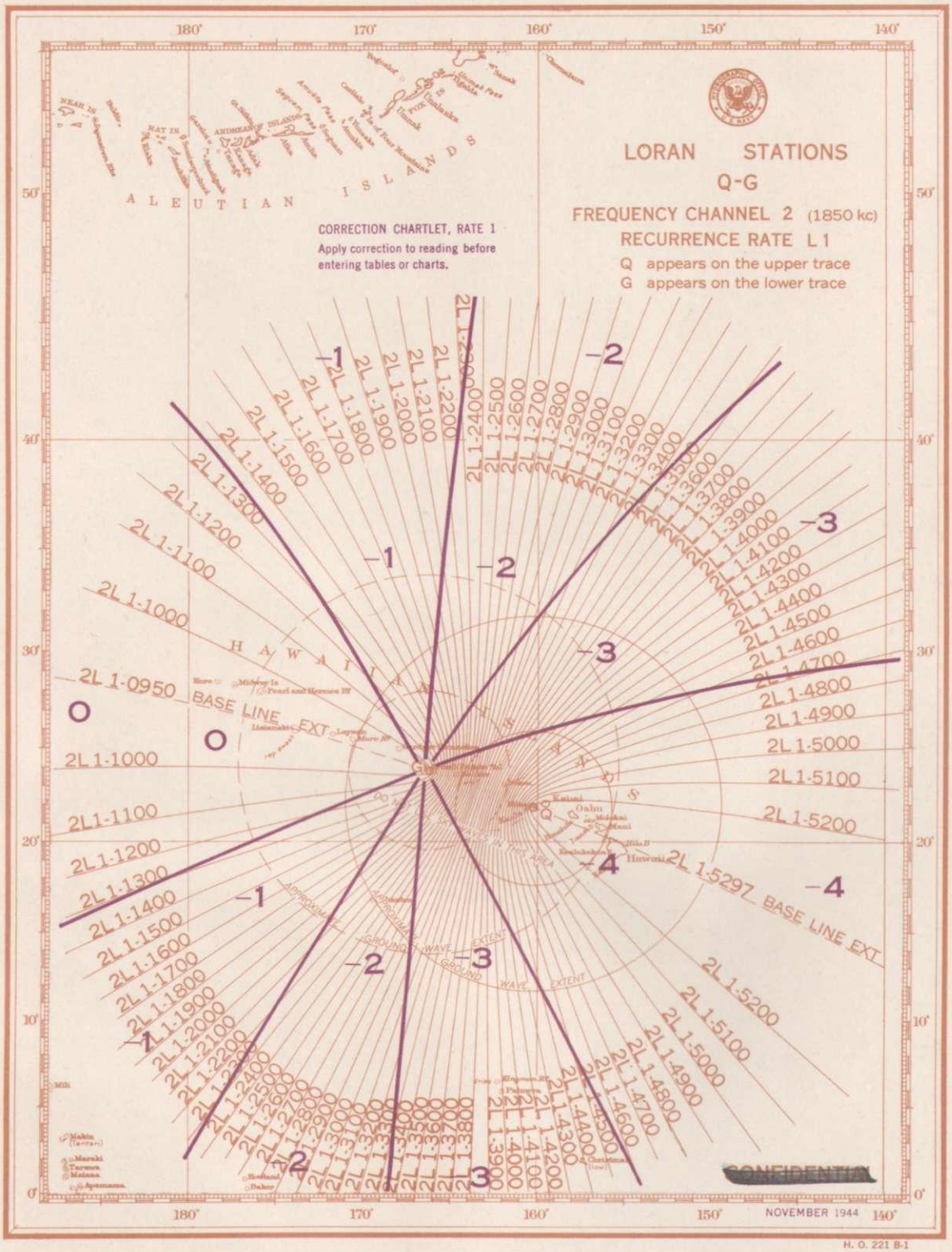
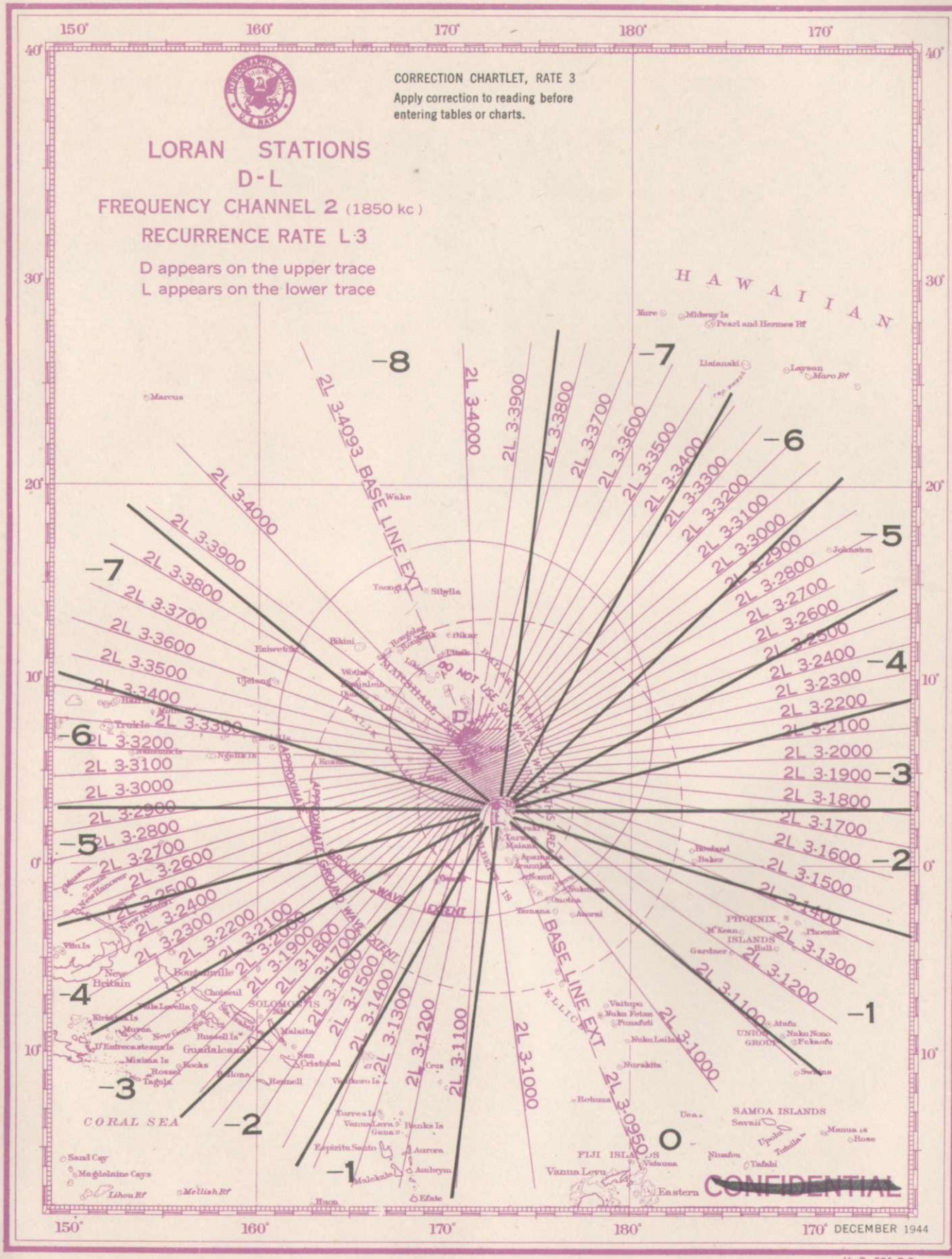

LORAN STATIONS
Q-G
FREQUENCY CHANNEL 2 (1850 kc)
RECURRENCE RATE L 1
Q appears on the upper trace
G appears on the lower trace
CORRECTION CHARTLET, RATE 1
Apply correction to reading before entering tables or charts.
ALEUTIAN ISLANDS
HAWAIIAN ISLANDS
2L 1-0950 BASE LINE EXT.
2L 1-5297 BASE LINE EXT.
APPROXIMATE GROUND WAVE EXTENT
CONFIDENTIAL
NOVEMBER 1944
H. O. 221 B-1


CORRECTION CHARTLET, RATE 3
Apply correction to reading before entering tables or charts.
LORAN STATIONS
D-L
FREQUENCY CHANNEL 2 (1850 kc)
RECURRENCE RATE L 3
D appears on the upper trace
L appears on the lower trace
150°
160°
170°
180°
170°
40°
30°
20°
10°
0°
HAWAIIAN
CORAL SEA
SOLOMON IS
FIJI ISLANDS
SAMOA ISLANDS
PHOENIX ISLANDS
Eastern
Marcus
Wake
Midway Is
Pearl and Hermes Rf
Lisianski
Laysan
Maro Rf
Johnston
Pikini
Bikar
Ujelang
Truk Is
Ngulu Is
Yap Is
Palau Is
New Britain
Bougainville
Choiseul
New Georgia Is
Russell Is
Guadalcanal
Malaita
San Cristobal
Rennell
Rendova
Kolombangara
Vella Lavella
Kieta
Buka Is
Mussau
Emirau
Manus
Kavieng
New Ireland
Rabaul
Baker
Howland
Gardner
Hull
McKean
Phoenix
Canton
Enderbury
Nukunau
Apamama
Tarawa
Maiana
Abemama
Makin
Onotoa
Tamana
Arorai
Nukufetau
Funafuti
Vaitupu
Nukulaelae
Nurakita
Rotuma
Savaii
Upolu
Tutuila
Manua Is
Rose
Niuafoo
Tafahi
Vatauna
Vanua Levu
Torres Is
Banks Is
Gaua
Espiritu Santo
Malekula
Aurora
Aoba
Efate
Huon
Sand Cay
Magdalaine Cays
Lihou Rf
Mellish Rf
-8
-7
-6
-5
-4
-3
-2
-1
0
2L 3·4093 BASE LINE EXT
2L 3·4000
2L 3·3900
2L 3·3800
2L 3·3700
2L 3·3600
2L 3·3500
2L 3·3400
2L 3·3300
2L 3·3200
2L 3·3100
2L 3·3000
2L 3·2900
2L 3·2800
2L 3·2700
2L 3·2600
2L 3·2500
2L 3·2400
2L 3·2300
2L 3·2200
2L 3·2100
2L 3·2000
2L 3·1900
2L 3·1800
2L 3·1700
2L 3·1600
2L 3·1500
2L 3·1400
2L 3·1300
2L 3·1200
2L 3·1100
2L 3·1000
2L 3·0950 BASE LINE EXT
DO NOT USE SKY WAVE
APPROXIMATE GROUND WAVE EXTENT
D
L
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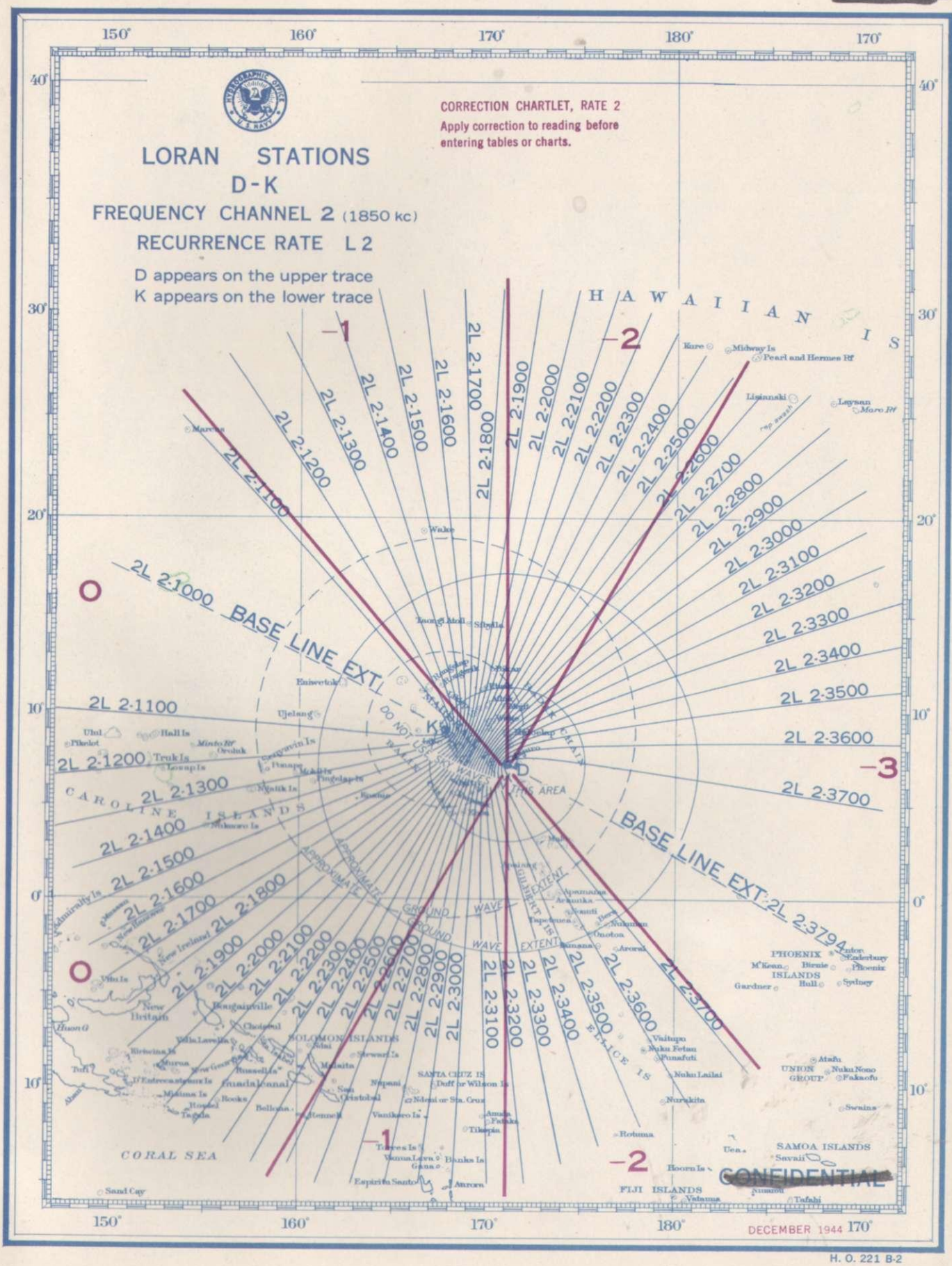
DECEMBER 1944


LORAN STATIONS
D-K
FREQUENCY CHANNEL 2 (1850 kc)
RECURRENCE RATE L 2
D appears on the upper trace
K appears on the lower trace
CORRECTION CHARTLET, RATE 2
Apply correction to reading before entering tables or charts.
HAWAIIAN IS
CAROLINE ISLANDS
CORAL SEA
SOLOMON ISLANDS
PHOENIX ISLANDS
SAMOA ISLANDS
FIJI ISLANDS
UNION GROUP
LINE ISLANDS
2L 2·1000 BASE LINE EXT.
BASE LINE EXT. 2L 2·3794
DO NOT USE THIS AREA
APPROXIMATE GROUND WAVE EXTENT
2L 2·1100
2L 2·1200
2L 2·1300
2L 2·1400
2L 2·1500
2L 2·1600
2L 2·1700
2L 2·1800
2L 2·1900
2L 2·2000
2L 2·2100
2L 2·2200
2L 2·2300
2L 2·2400
2L 2·2500
2L 2·2600
2L 2·2700
2L 2·2800
2L 2·2900
2L 2·3000
2L 2·3100
2L 2·3200
2L 2·3300
2L 2·3400
2L 2·3500
2L 2·3600
2L 2·3700
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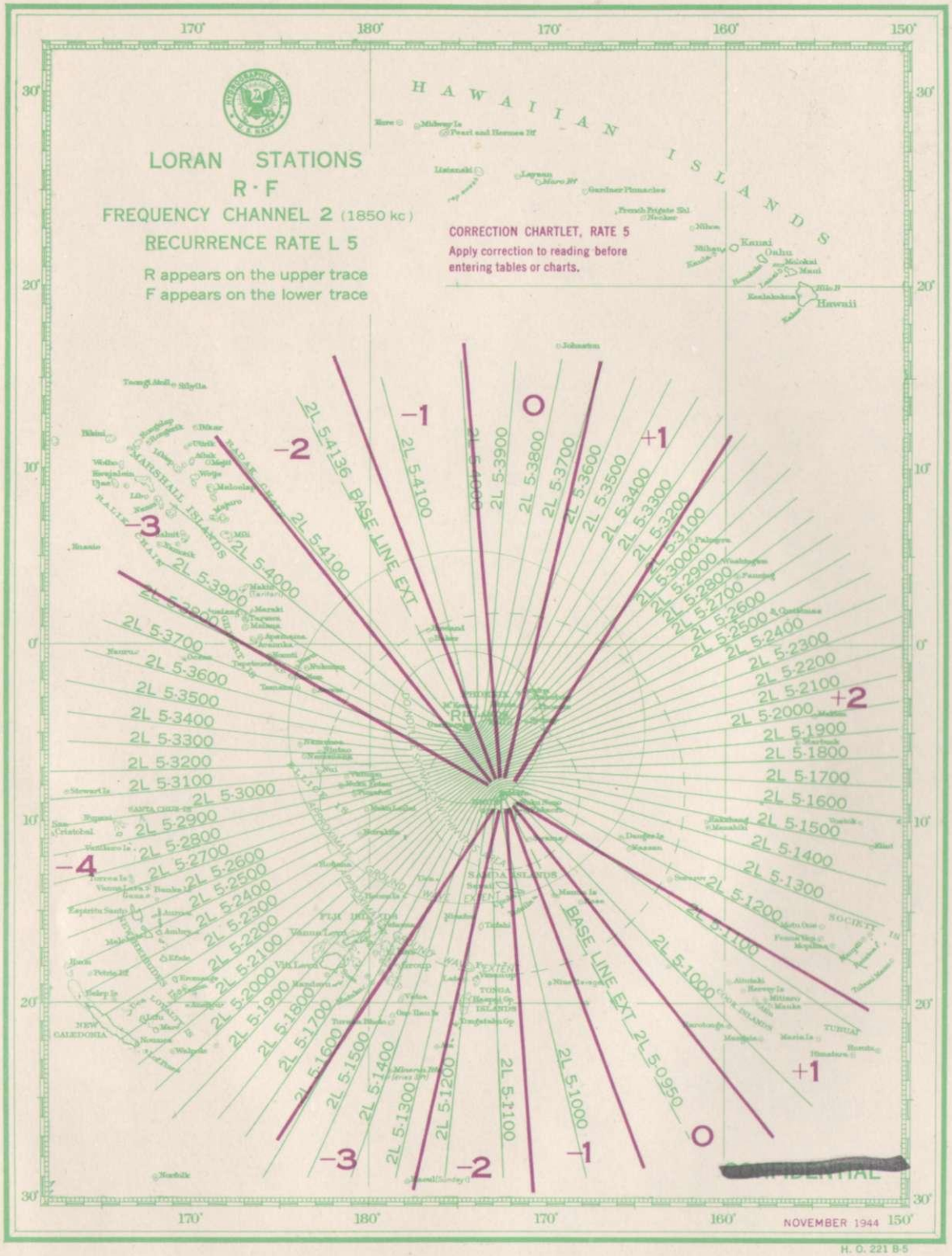
DECEMBER 1944
H. O. 221 B-2


LORAN STATIONS
R · F
FREQUENCY CHANNEL 2 (1850 kc)
RECURRENCE RATE L 5
R appears on the upper trace
F appears on the lower trace
CORRECTION CHARTLET, RATE 5
Apply correction to reading before entering tables or charts.
HAWAIIAN ISLANDS
Kauai
Oahu
Molokai
Maui
Hawaii
MARSHALL ISLANDS
SAMOA ISLANDS
SOCIETY IS.
TUBUAI
NEW CALEDONIA
2L 5-4136 BASE LINE EXT.
BASE LINE EXT. 2L 5-0950
-4
-3
-2
-1
0
+1
+2
NOVEMBER 1944

H. O. 221 B-5

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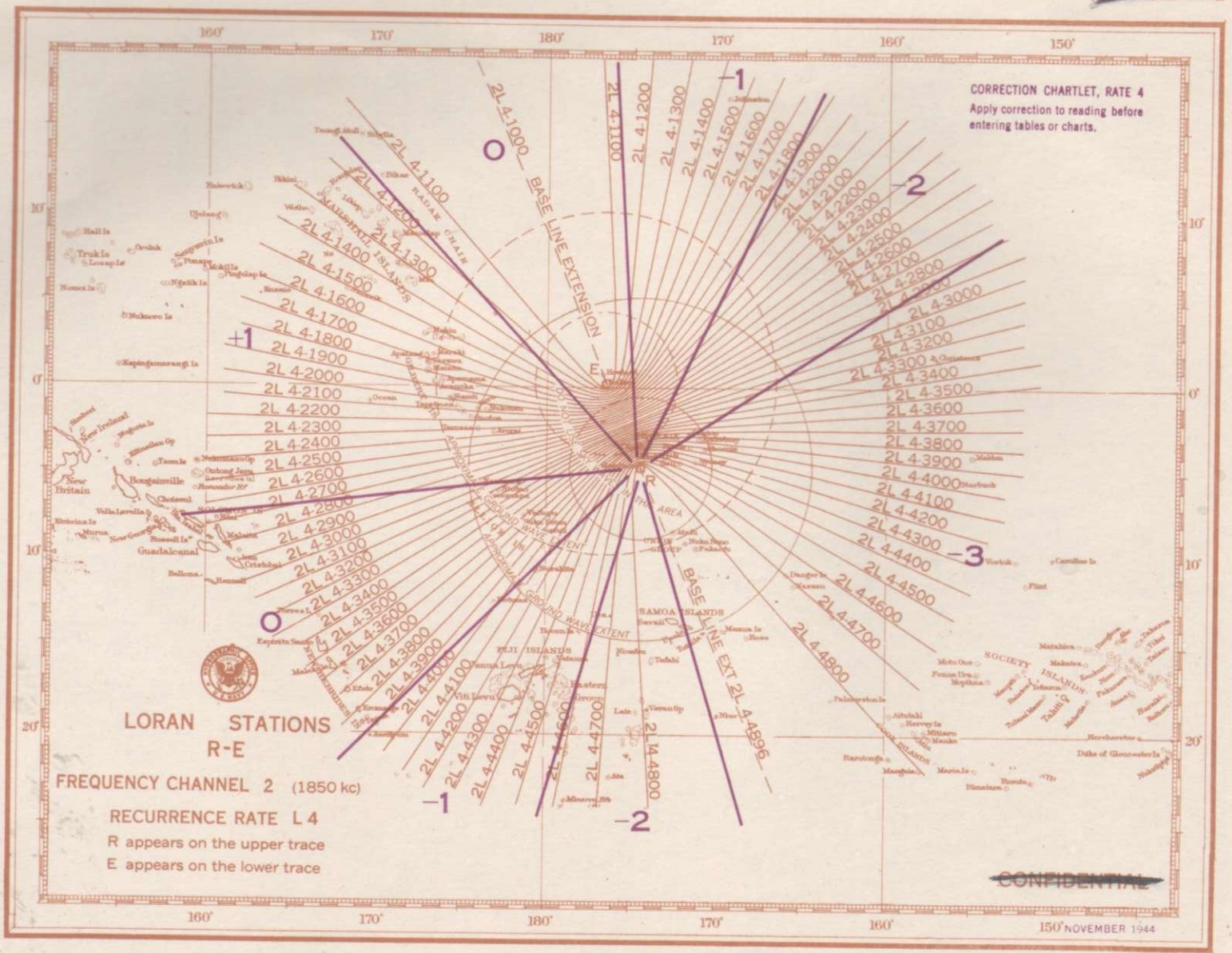

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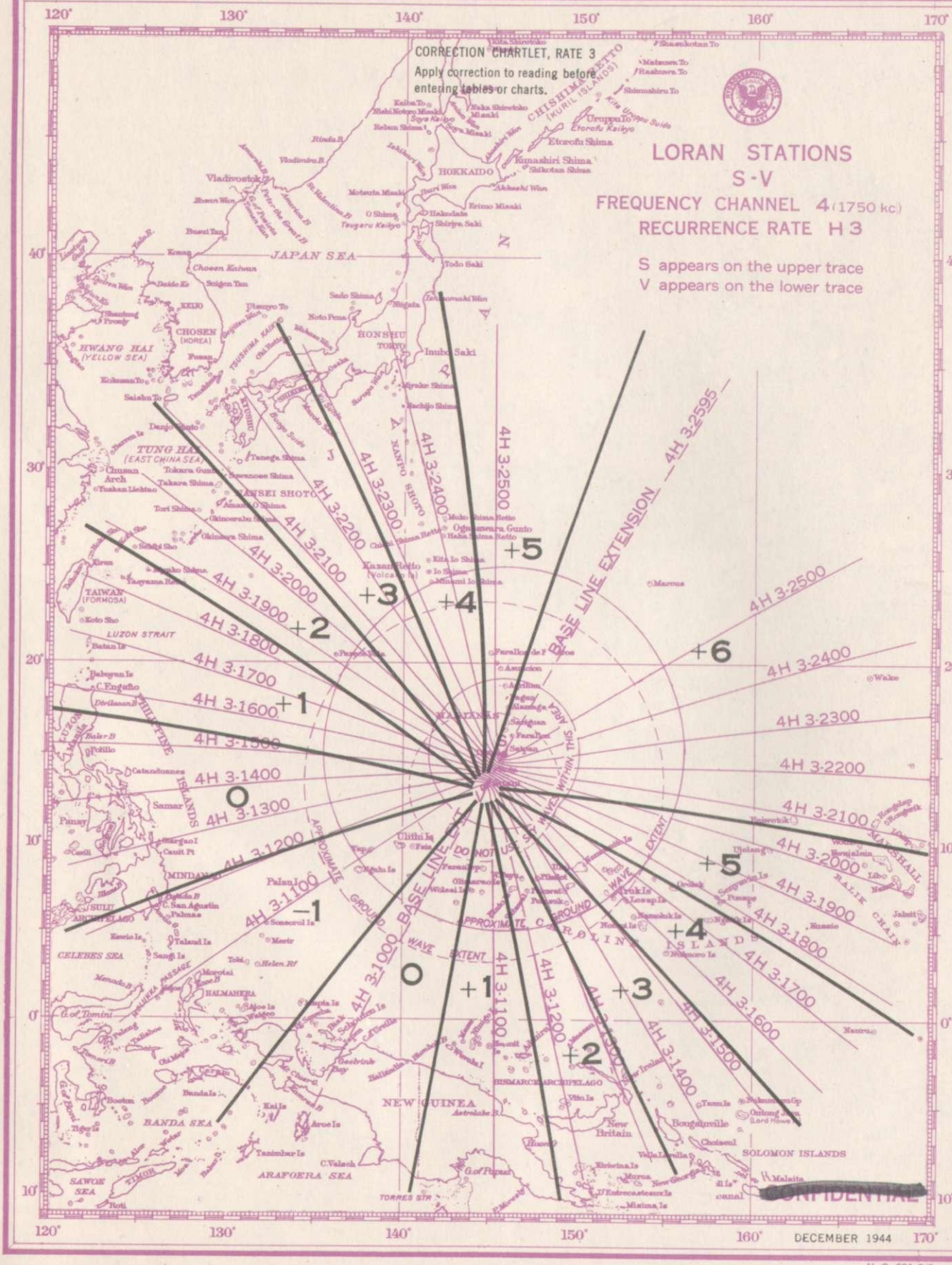
H. O. 221 B-4


CORRECTION CHARTLET, RATE 3
Apply correction to reading before entering tables or charts.
LORAN STATIONS
S-V
FREQUENCY CHANNEL 4 (1750 kc)
RECURRENCE RATE H 3
S appears on the upper trace
V appears on the lower trace
BASE LINE EXTENSION
4H 3·2595
4H 3·2500
4H 3·2400
4H 3·2300
4H 3·2200
4H 3·2100
4H 3·2000
4H 3·1900
4H 3·1800
4H 3·1700
4H 3·1600
4H 3·1500
4H 3·1400
4H 3·1300
4H 3·1200
4H 3·1100
4H 3·1000
+5
+3
+4
+2
+1
0
+6
+5
+4
+3
+2
+1
0
−1
BASE LINE
DO NOT USE WITHIN THIS WAVE EXTENT
APPROXIMATE GROUND WAVE EXTENT
JAPAN SEA
HOKKAIDO
HONSHU
CHOSEN (KOREA)
HWANG HAI (YELLOW SEA)
TUNG HAI (EAST CHINA SEA)
NANSEI SHOTO
NANTO SHOTO
TAIWAN (FORMOSA)
LUZON STRAIT
PHILIPPINE ISLANDS
CELEBES SEA
MOLUCCA PASSAGE
HALMAHERA
BANDA SEA
NEW GUINEA
ARAFOERA SEA
SAWOE SEA
TIMOR
TORRES STR.
MARIANAS
CAROLINE ISLANDS
MARSHALL ISLANDS
BISMARCK ARCHIPELAGO
SOLOMON ISLANDS
Vladivostok
Hakodate
Tokyo
Nagasaki
Manila
Palau Is
Truk Is
Ponape
Jaluit
Wake
Marcus
Rabaul
Bougainville
New Britain
Guam
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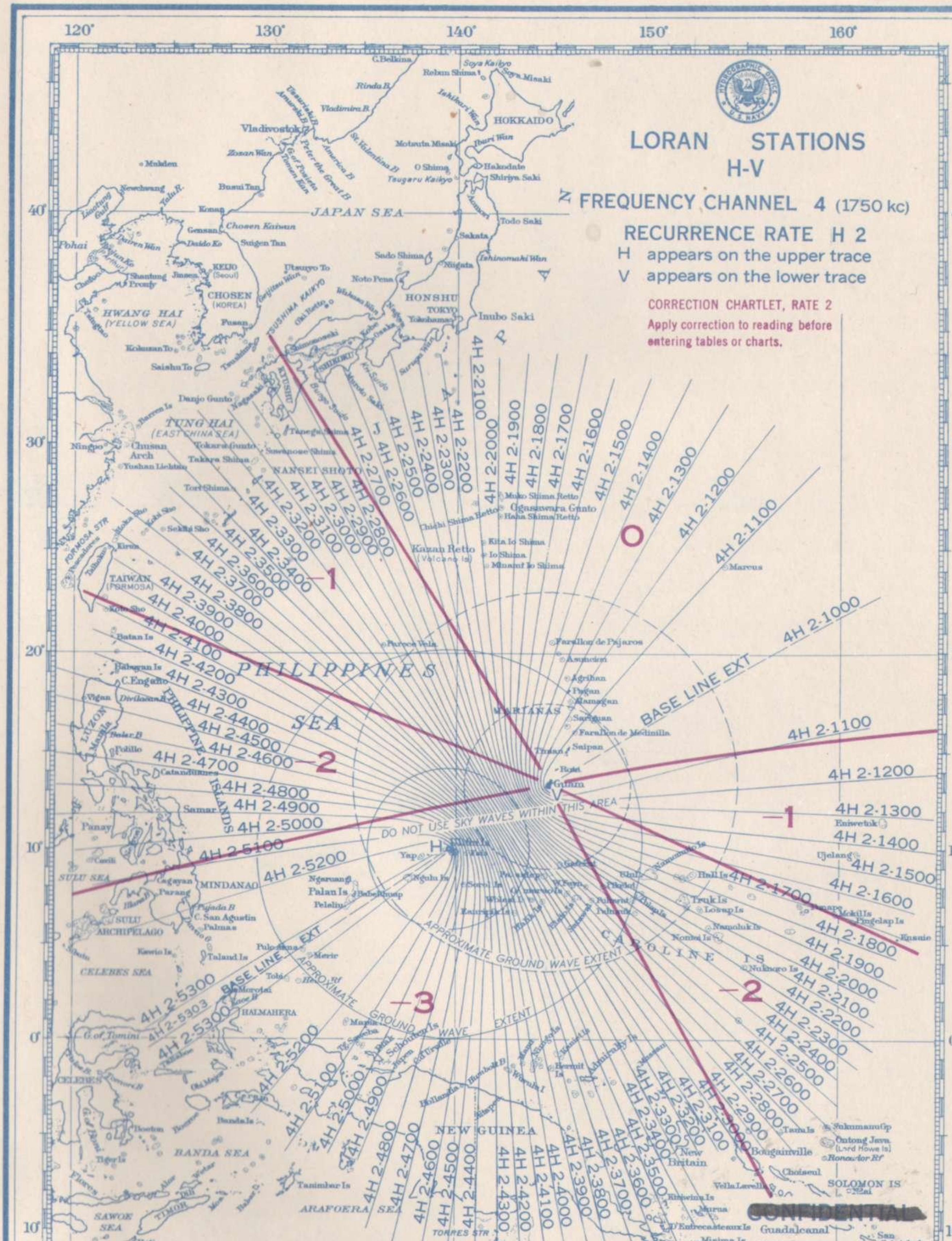
H. O. 221 C-3


LORAN STATIONS
H-V
FREQUENCY CHANNEL 4 (1750 kc)
RECURRENCE RATE H 2
H appears on the upper trace
V appears on the lower trace
CORRECTION CHARTLET, RATE 2
Apply correction to reading before entering tables or charts.
JAPAN SEA
PHILIPPINES SEA
DO NOT USE SKY WAVES WITHIN THIS AREA
APPROXIMATE GROUND WAVE EXTENT
BASE LINE EXT
CAROLINE IS
NEW GUINEA
BANDA SEA
CELEBES SEA
SULU SEA
HONSHU
HOKKAIDO
MINDANAO
MARIANAS
CONFIDENTIAL
JANUARY 1945